Foreword

This standard is developed by Sinopec Engineering Incorporation in cooperation with other involved organizations according to the requirements of Document JIANBIAO [2012] No. 5 issued by the Ministry of Housing and Urban-Rural Development(MOHURD) "Notice on Printing and Distributing 'the Development and Revision Plan of National Engineering Construction Standards in 2012'".

In preparing this standard, the development team carried out extensive investigations, summarized the engineering practices, made reference to the advanced codes and standards in China and abroad, requested and consolidated comments from involved organizations, reviewed and finalized this standard.

This standard consists of 5 chapters and 3 appendixes, covering: general provisions, terms and symbols, basic requirements, aseismatic measures appraisal and aseismatic calculations etc.

The provisions printed in bold type are mandatory ones and must be implemented strictly.

This standard is under the jurisdiction of, and its mandatory provisions are interpreted by the Ministry of Housing and Urban-Rural Development of the People's Republic of China. China Petro Chemical Corporation is responsible for its routine management, and Sinopec Engineering Incorporation is in charge of the explanation of technical specifications. During implementation of this standard, any comments and advices can be posted or passed on to Sinopec Engineering Incorporation (Address: Bldg.21 Anyuan, Anhui Bei Li, Chaoyang District, Beijing; Postcode: 100101).

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Contents

1 General provisions

1.0.1 This standard is developed for the purpose of reducing the earthquake damage to the existing electrical equipment in the industrial plants (hereafter shortened as electrical equipment), avoiding personnel injury and death, and lowering economic loss after the electrical equipment is seismically qualified and aseismatic measures are taken for attainment of the aseismatic precautionary criterion.

1.0.2 This standard is applicable to the aseismatic appraisal and aseismatic measures taken for the existing power transformers, reactors, circuit breakers, arresters, current transformers and potential transformers, electric porcelain equipment, capacitor groups (cabinets), battery banks (cabinets), switchgear cabinets, converter cabinets, control panels and relay panels, DC panels, emergency power supply units, gas insulated switchgears and other electrical equipment with rating voltage of 220kV and below in the areas where the design basic acceleration of earthquake ground motion is not larger than 0.40g (i.e., the aseismatic precautionary intensity is 9 degree and below).

This standard is not applicableto the areas where the design basic acceleration of earthquake ground motion is large than 0.40g or the existing electrical equipment in industrial plants for which special seismic requirements are specified.

1.0.3 For the electrical equipment that has been seismically qualified and corresponding aseismatic measures have been taken in accordance with this standard, they shall not be severely damaged in case of the earthquake intensity equal to and below the aseismatic precautionary intensity, and they may continue to supply power after minor repair.

1.0.4 For the electrical equipment without aseismatic precaution taken in the areas where the design basic acceleration of earthquake ground motion is 0.05g (i.e., the aseismatic precautionary intensity is 6 degree) and above, they must be seismically qualified and necessary aseismatic measures must be taken.

1.0.5 The design basic acceleration of earthquake ground motion and aseismatic precautionary intensity shall be determined in accordance with the current national standard GB 18306 *Seismic Ground Motion Parameters Zonation Map of China*. For the areas where the aseismatic precaution zoning maps have been developed or the project sites for which seismic safety assessments have been made, they may be seismically qualified per the approved design seismic ground motion parameters or the aseismatic precautionary intensity.

1.0.6 In addition to the requirements stipulated in this standard, those stipulated in the current relevant standards of the nation shall be complied with.

2 Terms and symbols

2.1 Terms

2.1.1 Aseismatic measures

The provisions specified in seismic design except for calculation of earthquake action and calculation of resistance, including the constructional measure for earthquake resistance.

2.1.2 Aseismatic precaution

The engineering and non-engineering precautionary measures taken for various structures against the possible earthquake hazard based on the specified reliability requirements.

2.1.3 Aseismatic precautionary criterion

A rule that is used to measure the aseismatic precautionary requirements and determined based on the aseismatic precautionary intensity or design ground motion parameters and aseismatic precautionary categories of the structures.

2.1.4 Aseismatic precautionary intensity

A seismic intensity that is approved by the related national administration authorities and used as a basis to determine the aseismatic precautionary rating for an area. Normally, the seismic intensity with a 10% probability of exceedance in 50 years is taken.

2.1.5 Aseismatic appraisal

The safety assessment that is made for the existing facilities under earthquake action by examining the design, construction quality and current state of the existing facilities in accordance with the aseismatic precautionary requirements.

2.1.6 Aseismic strengthening

The aseismatic design and construction made to enable the existing structures to attain the aseismatic qualification requirements.

2.1.7 Earthquake action

The dynamic action of the structure due to earthquake ground motion, including horizontal earthquake action and vertical earthquake action.

2.1.8 Earthquake action effect

The internal stress (shear stress, bending moment, axial stress and torsional moment, etc.) or deformation (linear displacement and angular displacement, etc.) of the structure generated by the seismic action.

2.1.9 Design basic acceleration of earthquake ground motion

The design acceleration of ground motion with a 10% probability of exceedance in 50 years.

2.2 Symbols

2.2.1 Earthquake action and action effect:

F—Earthquake action of the electrical equipment (structure);

m—Mass of the electrical equipment;

m_i—Mass concentrated at mass point i under operating conditions;

M—Bending moment;

T—Natural vibration period of the structure;

T_g—Characteristic period of ground motion;

σ—Tensile (compression) stress;

τ—Shear stress;

g—Acceleration of gravity.

2.2.2 Material performance

E—Modulus of elasticity of the material;

K—Lateral rigidity of the system;

σ—Tensile (compression) stress;

τ—Shear stress;

$[\sigma]$—Design allowable stress;

$[\tau]$—Design allowable shear stress.

2.2.3 Geometric parameters:

A—Area of cross section;

d—ID of circumferential cross section;

D—OD of circumferential cross section;

H—Height of the structure;

H_i—Calculated height of mass point i;

I—Second axial moment of area;

W—Modulus of section;

Z—Area moment of inertia.

2.2.4 The factors and coefficients used in calculations:

k—Unbalance factor;

α—Seismic influence factor;

α_{max}—Maximum seismic influence factor;

β—Floor dynamic magnification factor;

λ—Rigidity reduction coefficient;

r—Modal participation coefficient.

3 Basic requirements

3.0.1 The electrical equipment shall be classified into critical electrical equipment and general electrical equipment based on the following requirements:

1 Critical electrical equipment: including the electrical equipment that is rated in voltage levels of 110kV and 220kV or used to supply power to the first grade loads in enterprises and the electrical equipment that is required to secure power supply in case of earthquake.

2 General electrical equipment: including the equipment other than those specified in Item 1.

3.0.2 Visual examination shall be performed for aseismatic appraisal of electrical equipment, and the following requirements shall be complied with:

1 The equipment itself shall be free of any damage, and the porcelain insulators shall be free of any crack.

2 The electrical connections shall be reliable, the bolting shall be in good conditions, and the nuts shall not be loose.

3 The connections between the equipment and foundation/the support structure shall be firm.

4 The welds shall be free of any crack, and the metal parts shall be free of any severe corrosion.

5 The equipment supporting structures and attachments shall be free of any deformation or damage.

3.0.3 The seismic effect may be characterized by the following ground motion parameters for area where the electrical equipment is installed:

1 The design basic acceleration of earthquake ground motion or aseismatic precautionary intensity.

2 The characteristic period of ground motion.

3.0.4 The correlation between design basic acceleration of earthquake ground motion and aseismatic precautionary intensity is shown in Table 3.0.4.

Table 3.0.4 Correlation between design basic acceleration of earthquake ground motion and aseismatic precautionary intensity

Design basic acceleration of earthquake ground motion	0.05g	0.10g	0.15g	0.20g	0.30g	0.40g
Aseismatic precautionary intensity	6	7		8		9

Note: g is the acceleration of gravity, and it is taken as $9.8 m/s^2$.

3.0.5 Aseismatic calculation shall be provided for the power transformers, vertically installed three-phase reactors and arrestors, circuit breakers and porcelain bushings for one of the following cases:

1 The area where the design basic acceleration of earthquake ground motion is 0.20g and above.

2 The areas where the design basic acceleration of earthquake ground motion is 0.10g and 0.15g and the voltage level is 110kV and 220kV.

3 The area where the design basic acceleration of earthquake ground motion is 0.15g and the height of floor or support on which the electrical equipment is installed is higher than 2.0m.

3.0.6 Aseismatic calculation may not be provided for the following electrical equipment; however, aseismatic appraisal shall be provided for the fixing methods and the construction of the electrical equipment, and corresponding aseismatic measures shall be taken.

1 The capacitor groups (cabinets), battery banks (cabinets), switchgear cabinets, converter cabinets, control (relay) panels, DC panels, emergency power supply units, gas insulated switchgears and other electrical equipment.

2 The racks used to install the electrical equipment.

3 The electrical equipment other than those specified in Article 3.0.5 of this standard.

3.0.7 The earthquake action of the critical electrical equipment shall be calculated by one level higher than the design basic acceleration of earthquake ground motion for the area where the equipment is installed, and the seismic measure shall be provided one level higher than the aseismatic precautionary intensity specified for this area. If the aseismatic precautionary intensity is 9 degree, the design basic acceleration of earthquake ground motion used to calculate the earthquake action may not be further increased, the aseismatic measures may be properly strengthened.

3.0.8 If the electrical equipment fails to meet the aseismatic appraisal requirements, aseismatic measures shall be taken or shock-absorbing measures shall be taken in accordance with Appendix A of this standard.

3.0.9 Unless otherwise specified in this standard, the design allowable stress used in aseismatic calculation for electrical equipment shall be selected in accordance with the following requirements:

1 The design allowable stress for elastic materials may be 1.4 times the allowable stress of the materials at design temperature, but it shall not be larger than 0.9 time the yield strength of the materials at design temperature.

2 The design allowable stress for brittle materials may be 1.2 times the design tensile strength of the materials or 0.6 time the breaking stress of the materials at design temperature.

3.0.10 Various electrical equipment shall be reliably fixed onto the foundation, bases or racks, and the equipment anchor bolts or welding strength shall meet the aseismatic precaution requirements.

3.0.11 In the areas where the design basic acceleration of earthquake ground motion is 0.20g and above, the power distribution equipment installed at high positions or on multi-layers should be relocated on lower positions or aseismatic measures should be taken, and the tubular bus should be suspension installed.

3.0.12 Flexible conductors should be used to connect the electrical equipment lead wires and equipment, and proper length margin shall be provided for the flexible conductors. If rigid bus is used for connection, flexible fitting shall be provided for transition.

4 Aseismatic measures appraisal

4.1 Power transformers

Ⅰ General requirements

4.1.1 The power transformers shall include the transformers and arc suppression coils.

4.1.2 Aseismatic appraisal for power transformers shall focus on examination of the installation methods, the connections between the lead wires and external wires, and the strength of the conservator racks and the radiator cantilevers.

4.1.3 In the areas where the aseismatic precautionary intensity is 7 degree and above, aseismatic calculation shall be made in accordance with Chapter 5 of this standard.

Ⅱ Aseismatic appraisal

4.1.4 Aseismatic appraisal for transformers and arc suppression coils shall meet the following requirements:

1 The transformer and arc suppression coil shall be securely fixed to the foundation.

2 Flexible conductoring shall be provided between the transformer and the external bus.

3 The transformer conservator rack shall be free of any visible deformation, and shall be securely fixed with the main body of the transformer and the conservator.

4 The cantilever radiator of the transformer and the connections shall be in good conditions.

4.1.5 The connection pipe between the independent oil cooler and the main body of the transformer shall be provided with shut-off valve and flexible fitting near to the transformer.

4.1.6 The power transformers installed on the electric poles shall be provided with fixing devices.

Ⅲ Aseismatic measures

4.1.7 If the transformers and arc suppression coils fail to meet the aseismatic appraisal requirements in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 In addition to displacement limit measures, the transformers and arc suppression coil shall be directly bolted or welded to the foundation.

2 If flexible conductors are used for the transformer bushings, proper slack shall be provided. If the insulation clearance fails to meet the specified requirements, spring clamp fittings may be used. If rigid bus is used and the size of bus section is larger than 50mm×5mm, flexible fittings shall be provided. If the aseismatic precautionary intensity is 6 degree or 7 degree, flexible fittings should be provided for the power transformers of 10kV and below. And if the aseismatic precautionary intensity is 8 degree or 9 degree, flexible conductor shall be provided.

3 The cantilever radiator of the transformer may be supported by the angle steel rack installed on the main body of the transformer or fixed circularly around the radiator by using flat steel strips.

4.1.8 The connection pipe between the independent oil cooler and the main body of the transformer shall be provided with shutoff valve and flexible fitting near to the transformer, and the distance from the radiator, oil-submerged pump and connection pipe to the foundation shall not be less than 200mm.

4.1.9 The bottom of transformers installed on electric pole shall be bolted to the lower beam. In the area where the aseismatic precautionary intensity is 8 degree and above, fixing devices should be also provided between the upper portion of the transformer and the electric pole.

4.2 Vertically installed three-phase reactors

I General requirements

4.2.1 Vertically installed three-phase reactors shall include vertically installed three-phase cement reactors and vertically installed three-phase dry hollow core reactors.

4.2.2 Aseismatic appraisal for vertically installed three-phase reactors shall focus on the examination of the reactor models and installation methods.

4.2.3 Aseismatic calculations shall be made for the vertically installed three-phase cement reactors used in the areas where the aseismatic precautionary intensity is 7 degree and above and the vertically installed three-phase dry hollow core reactors used in the areas where the aseismatic precautionary intensity is 8 degree and above in accordance with Chapter 6 of this standard.

II Aseismatic appraisal

4.2.4 The aseismatic appraisal for vertically installed three-phase reactors shall meet the following requirements:

1 Vertically installed three-phase reactors should be dry hollow core reactors.

2 Three-phase reactors should be horizontally installed.

III Aseismatic measures

4.2.5 If the vertically installed three-phase reactors fail to meet the aseismatic appraisal requirements in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 In the areas where the aseismatic precautionary intensity is 6 degree or 7 degree, the vertically installed three-phase cement reactors should be changed to dry hollow core reactors, and in the areas where the aseismatic precautionary intensity is in 8 degree or 9 degree, the vertically installed three-phase cement reactors shall be changed to dry hollow core reactors.

2 Vertically installed three-phase reactors should be changed to horizontally installed reactors where site conditions permit.

4.2.6 For the vertically installed three-phase dry air-core reactors used in the areas where the aseismatic precautionary intensity is 8 degree and above and the vertically installed three-phase cement reactors, if their aseismatic calculation fail to meet the aseismatic appraisal requirements, seismic strengthening may be made in accordance with Appendix B of this standard.

4.2.7 For the supporting porcelain insulators of the vertically installed three-phase dry air-core reactors in the areas where the aseismatic precautionary intensity is 7 degree and below or for the supporting porcelain insulators of the horizontally installed three-phase cement reactors, if their aseismatic calculation fail to meet the aseismatic appraisal requirements, such supporting porcelain insulators shall be replaced with the insulators in higher strength.

4.3 Circuit breakers and arresters

I General requirements

4.3.1 The circuit breakers and the arresters include independent circuit breakers, free standing arresters and tie-rod arresters.

4.3.2 Aseismatic appraisal for the circuit breakers and the arresters shall focus on the examination of the porcelain insulators, the connections between porcelain insulators and flanges, and the strength of tie-rod and external conductors at each direction.

4.3.3 In the areas where the aseismatic precautionary intensity is 7 degree and above, the circuit breakers and the arresters shall be seismically calculated in accordance with Chapter 5 of this standard.

Ⅱ Aseismatic appraisal

4.3.4 Aseismatic appraisal for the circuit breakers and the arresters shall meet the following requirements:

1 The porcelain insulators of the circuit breakers and the arresters shall be in good conditions.

2 The porcelain insulators and the flanges shall be firmly attached.

3 The bases and intermediate flanges of the circuit breakers and the arresters shall be in good conditions, and the nuts shall not be loose.

4 The external conductors of the circuit breakers and the arresters shall be flexible conductor or provided with flexible fittings.

4.3.5 For the arresters provided with insulated tie-rods, the strength of the tie-rods at each direction shall be uniform.

Ⅲ Aseismatic measures

4.3.6 If the circuit breakers and the arresters fail to meet the aseismatic appraisal requirements specified in this section, aseismatic precaution measures shall be taken in accordance with the following requirements or shock-absorbing measures shall be taken in accordance with Appendix A of this standard.

1 The damaged or cracked porcelain insulators of the circuit breakers and the arresters shall be replaced with good porcelain insulators.

2 The bolts used to fix the porcelain insulator and the flange shall be tightened.

3 If the bases and intermediate flanges of the circuit breakers and the arresters are corroded, rust shall be removed and nuts shall be tightened.

4 If rigid bus or tubular bus is used as the external conductors for the circuit breakers and the arresters, flexible conductor or flexible fittings shall be provided.

4.3.7 For the arresters with insulated tie-rods, the strength of the tie-rods at each direction shall be uniform. If the insulated tie-rods are damaged or fail to meet the strength requirements, they shall be replaced.

4.4 Capacitor groups (cabinets)

Ⅰ General requirements

4.4.1 The capacitor groups (cabinets) shall include the capacitors installed on the racks, on the ground, inside/outside the cabinets, individually installed or group installed.

4.4.2 Aseismatic appraisal for capacitor groups (cabinets) shall focus on examination of the installation methods and the connection with external conductors.

4.4.3 Aseismatic calculation may not be provided for the capacitor groups (cabinets).

Ⅱ Aseismatic appraisal

4.4.4 The aseismatic appraisal for capacitor groups (cabinets) shall meet the following requirements:

1 The capacitor groups (cabinets) shall be securely fixed to the foundation.

2 The lead wires of capacitors should be flexible conductors.

Ⅲ Aseismatic measures

4.4.5 If the capacitor groups (cabinets) fail to meet the aseismatic appraisal requirements specified in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 The bases of the capacitor groups (cabinets) shall be securely fixed to the supporting structures by using anchor bolts.

2 Hard conductors should not be used as the lead wires of the capacitors, and hard conductors shall be provided with flexible fittings or replaced with flexible conductors in the case that the aseismatic precautionary intensity is 7 degree to 9 degree.

4.5 Electric porcelain equipment

Ⅰ General requirements

4.5.1 The electric porcelain equipment include the electrical equipment for which porcelain insulators are their main parts, but exclude the circuit breakers and the arresters.

4.5.2 The aseismatic appraisal for electric porcelain equipment shall focus on examination of the installation methods, the connections of porcelain insulators and the types of porcelain insulators.

4.5.3 Aseismatic calculation may not be provided for the electric porcelain equipment.

Ⅱ Aseismatic appraisal

4.5.4 The aseismatic appraisal for electric porcelain equipment shall meet the following requirements:

1 In the areas where the aseismatic precautionary intensity is 7 degree and above, the porcelain insulators should be high strength type.

2 The lead wires of HV electric porcelain equipment should be flexible conductors.

3 In the areas where aseismatic precautionary intensity is 8 degree or 9 degree, HV electric porcelain equipment with voltage rating of 110kV and above shall be arranged at low positions or in mono-layer.

4 The bases of current (potential) transformers shall be securely fixed to the foundations.

Ⅲ Aseismatic measures

4.5.5 If the electric porcelain equipment fails to meet the aseismatic appraisal requirements specified in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 In the areas where the aseismatic precautionary intensity is ranged from 7 degree to 9 degree, the general porcelain insulators should be changed to high strength porcelain insulators.

2 In the areas where the aseismatic precautionary intensity is ranged from 7 degree to 9 degree, the lead wires of HV electric porcelain equipment should be flexible conductors. If hard conductors are used, they shall be provided with flexible fittings or replaced with flexible conductors.

3 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, HV electric porcelain equipment with voltage rating of 110kV and above arranged at high positions or superposed should be relocated at low positions or in mono-layer.

4 The bases of the current (voltage) transformers shall be securely fixed to the supporting structures by using anchor bolts.

4.6 Battery

Ⅰ General requirements

4.6.1 The batteries equipment shall include glass tank type battery banks and free standing maintenance-free batteries.

4.6.2 Aseismatic appraisal for the batteries shall focus on examination of the installation methods and the connections with external conductors.

4.6.3 Aseismatic calculation may not be provided for the batteries.

Ⅱ Aseismatic appraisal

4.6.4 The aseismatic appraisal for the batteries shall meet the following requirements:

1 The batteries shall be provided with measures against displacement, toppling or dropping.

2 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, provisions shall be provided between the cell units of the glass tank type battery banks to avoid collision.

3 The restraint supports for glass tank type battery cells shall not interfere with the battery maintenance and inspection.

4 Flexible conductors or cables shall be used for the connections between the battery cells.

Ⅲ Aseismatic measures

4.6.5 If the batteries fail to meet the aseismatic appraisal requirements specified in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 The batteries shall be provided with restraints to prevent the cells from displacing, falling or toppling. Battery racks attached to the supporting structures may be used.

2 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, spacers or cushions shall be provided between the cell units of the glass tank type battery bank.

3 The height of the restraint support for the glass tank type battery shall be higher than the height of the center of gravity of the battery, but it shall not interfere with the battery maintenance and inspection.

4 Flexible conductors or cables should be used for connection between the battery cells, and cables shall be used as the lead wires of the terminal battery cells.

4.7 Panels, cabinets, distribution boxes and GIS

Ⅰ General requirements

4.7.1 The panels, cabinets, distribution boxes and GIS include various switchgears, control panels, relay panels, distribution boxes, emergency power supply units and gas insulated switchgears.

4.7.2 Aseismatic appraisal for panels, cabinets and distribution boxes shall focus on examination of the construction of the panels, cabinets and distribution boxes and their installation methods.

4.7.3 Aseismatic calculation may not be provided for the panels, cabinets and distribution boxes.

Ⅱ Aseismatic appraisal

4.7.4 Aseismatic appraisal for the panels, cabinets and distribution boxes shall meet the following requirements.

1 The bases of various panels, cabinets and distribution boxes shall be securely fixed to the foundation.

2 The withdrawable electrical devices in the switchgear cabinets shall be provided with lock mechanism.

3 Secondary cable plugs in switchgear shall not be loose.

4 The relays and meters provided in switchgears and control (relay) panels shall be all securely fixed.

5 The oil immersed potential transformers in switchgears shall be securely fixed.

6 The printed circuit plugs and plug boards in the control (relay) panels shall not be loose.

7 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, the switchgear cabinets, power distribution panels and control (relay) panels arranged in rows shall be connected together. If the cabinets (panels) are located at the settlement joint or expansion joint of the building, the rigid buses between them shall be provided with flexible conductor.

4.7.5 The aseismatic appraisal for GIS shall meet the following requirements:

1 The gas insulated switchgears shall be firmly attached to the foundation.

2 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, the gas insulated switchgears should not be located at the settlement joint, expansion joint or seismic joint of the building.

Ⅲ Aseismatic measures

4.7.6 If the panels, cabinets and distribution boxes fail to meet the aseismatic appraisal requirements specified in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 The bases of the switchgear cabinets, converter cabinets, control (relay) panels, DC panels and other emergency power supply units shall be securely attached to the supporting structures by using at least 4 bolts, and at least 1 bolt shall be provided at each corner. If the length of the each electrical equipment is larger than 1.0m, additional bolts shall be used or the requirements specified by the electrical equipment manufacturers shall be followed to fix the electrical equipment, the bases of the cabinets or panels may be welded to the supporting structures, the locations and number of welds shall be the same as those for bolting method, the length of each weld shall not be less than 40mm, and the leg height shall not be less than the thickness of the weldment.

2 The withdrawable electrical devices in the switchgear cabinets shall be provided with lock mechanism.

3 The secondary cable plugs in switchgear shall be provided with measures against loosening.

4 The relays and meters provided in switchgear cabinets and control (relay) panels shall be all securely fixed with bolts or clamps.

5 The oil immersed potential transformers in switchgears shall be bolted to the chassis.

6 The printed circuit plugs and plug boards in the control (relay) panels shall be provided with lock devices against loosening.

7 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, the switchgear cabinets, power distribution panels and control (relay) panels arranged in rows shall be bolted together above the center of gravity of the equipment. If the cabinets (panels) are located at the settlement joint or expansion joint of the building, the rigid buses between them shall be provided with flexible conductor.

4.7.7 If GIS fail to meet the aseismatic appraisal requirements specified in this section, aseismatic measures shall be taken in accordance with the following provisions:

1 The bases of GIS shall be securely fixed to the foundation by using anchor bolts.

2 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, GIS should not be located at the settlement joint, expansion joint or seismic joint of the building.

5 Aseismatic calculations

5.1 Calculation of earthquake action

5.1.1 The methods for calculating the earthquake action of electrical equipment should be in accordance with the following requirements:

1 Simplified methods such as base shear method may be used for the structures that are not higher than 30m and mainly involved with shearing deformation and for the electrical equipment (including the part above the foundation surface) that is approximate to single mass point system.

2 Mode response spectrum method should be used for the electrical equipment other than those specified in Item 1 of Article 5.1.1.

5.1.2 The seismic influence factor of the electrical equipment (or structure) installed on the ground shall be determined based on the aseismatic precautionary intensity or design basic acceleration of earthquake ground motion, design earthquake group, site class, natural vibration period of the structure and the damping ratio of the structure (Figure 5.1.2). The maximum horizontal seismic influence factor shall be determined according to those specified in Table 5.1.2-1, and the characteristic period shall be determined according to those specified in Table 5.1.2-2 based on the site class and design earthquake group.

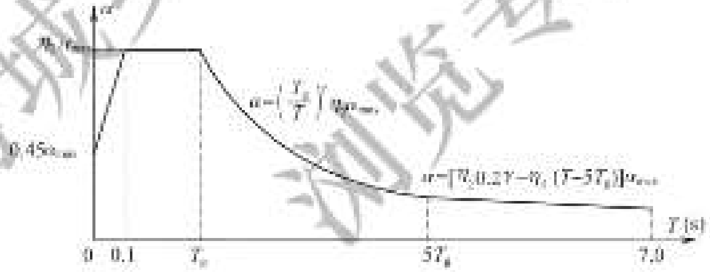

Figure 5.1.2 Seismic influence factor curve

α—Seismic influence factor; α_{max}—Maximum seismic influence factor;

η_1—Descending slope modifying coefficient of the decline line; γ—Attenuation index;

T_g—Characteristic period; η_2—Damping adjustment coefficient; T—Natural vibration period of the structure

Table 5.1.2-1 Maximum horizontal seismic influence factor

Aseismatic fortification intensity	6 degree	7 degree		8 degree		9 degree
Design basic acceleration of earthquake ground motion	0.05g	0.10g	0.15g	0.20g	0.30g	0.40g
Maximum horizontal seismic influence factor	0.12	0.23	0.34	0.45	0.67	0.90

Table 5.1.2-2 Values of characteristic period (s)

Design earthquake group	Site class				
	Ⅰ₀	Ⅰ₁	Ⅱ	Ⅲ	Ⅳ
Grouping Ⅰ	0.20	0.25	0.35	0.45	0.65
Grouping Ⅱ	0.25	0.30	0.40	0.55	0.75
Grouping Ⅲ	0.30	0.35	0.45	0.65	0.90

5.1.3 The damping adjustment and form parameters of the seismic influence factor curve shall be in accordance with the following requirements:

1 Where the damping ratio of the structure is equal to 0.05, the damping adjustment coefficient of the seismic influence factor curve shall be equal to 1.0, and the form parameters shall be in accordance with the following requirements:

1) The linear ascending section shall be the segment with period less than 0.1s.

2) The horizontal section shall be the segment from 0.1s to the characteristic period, and the maximum seismic influence factor (α_{max}) shall be taken.

3) The descending curve shall be the segment from the characteristic period to 5 times of characteristic period, and the attenuation index shall be equal to 0.9.

4) The descending straight line shall be the segment from 5 times of characteristic period to 7s, and the descending slope modifying coefficient shall be equal to 0.02.

2 Where the damping ratio is not equal to 0.05, the damping adjustment coefficient and the form parameters of the seismic influence factor curve shall be in accordance with the following requirements:

1) The attenuation index of the descending curve shall be calculated according to the following formula:

$$\gamma = 0.9 + \frac{0.05 - \zeta}{0.3 + 6\zeta} \tag{5.1.3-1}$$

Where, γ —Attenuation index of the descending curve;

ζ —Damping ratio.

2) The descending slope modifying coefficient of the descending straight line shall be calculated according to the following formula:

$$\eta_1 = 0.02 + \frac{0.05 - \zeta}{4 + 32\zeta} \tag{5.1.3-2}$$

Where, η_1—Descending slope modifying coefficient of the descending straight line, if it is less than 0, then it shall be equal to 0.

3) The damping adjustment factor shall be calculated according to the following formula:

$$\eta_2 = 1 + \frac{0.05 - \zeta}{0.08 + 1.6\zeta} \tag{5.1.3-3}$$

Where, η_2—Damping adjustment factor, it shall be equal to 0.55 if the damping adjustment factor is less than 0.55.

5.1.4 The damping ratio of electrical equipment (or structure) may be determined according to those specified in Table 5.1.4.

Table 5.1.4 Damping ratio of electrical equipment (or structure)

Types of electrical equipment (or structure)	Steel equipment (including steel structure)	Reinforced concrete structure	Electric porcelain equipment
Damping ratio	0.04	0.05	0.02

5.1.5 Where base shear method is used, the nominal horizontal earthquake action (Figure 5.1.5) may be calculated according to the following formulas:

$$F_H = \alpha_1 m_{eq} g \tag{5.1.5-1}$$

$$m_{eq} = \lambda_{eq} \sum_{i=1}^{n} m_i \tag{5.1.5-2}$$

$$F_i = \frac{m_i H_i^{\delta}}{\sum_{i=1}^{n} m_i H_i^{\delta}} \qquad (5.1.5\text{-}3)$$

Where, F_{Ek}—Standard value of the total horizontal earthquake action of the electrical equipment (or structure)(N);

g—Acceleration of gravity (m/s^2), it is equal to 9.8;

α_1—Horizontal seismic influence factor corresponding to the fundamental period of the electrical equipment (or structure);

m_{eq}—Total equivalent mass of the electrical equipment (or structure) under operating conditions (kg);

λ_{eq}—Equivalent mass coefficient, it is equal to 1 for single mass point system, and it is equal to 0.85 for multiple mass point system;

F_i—Nominal horizontal earthquake action applied at mass point i (N);

m_i—Mass concentrated at mass point i under operating conditions (kg);

H_i—Calculated height of mass point i (m);

n—Number of mass points;

δ—Bending deformation influence index of the electrical equipment (or structure), it shall be determined according to those specified in Table 5.1.5.

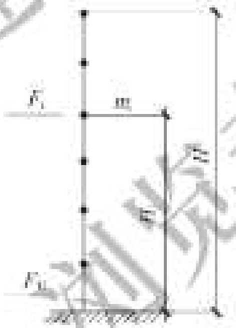

Figure 5.1.5 Nominal horizontal earthquake action

Table 5.1.5 Bending deformation influence index

Fundamental period of electrical equipment (or structure)	<0.5	0.5—2.5	>2.5
δ	1.0	$0.75+0.5T_1$	2

Note: T_1 is the fundamental period of the equipment (s).

5.1.6 Where mode response spectrum method is used, calculation of nominal earthquake action effect of the electrical equipment (or structure) shall be in accordance with the following requirements:

1 The normal horizontal earthquake action of mass point i of mode j of the electrical equipment shall be calculated according to the following formulas:

$$F_{ji} = \alpha_j \gamma_j X_{ji} m_i g \qquad (5.1.6\text{-}1)$$

$$\gamma_j = \frac{\sum_{i=1}^{n} X_{ji} m_i}{\sum_{i=1}^{n} X_{ji}^2 m_i} \qquad (5.1.6\text{-}2)$$

$$(i=1,2,\cdots,n;j=1,2,\cdots,k)$$

Where, F_{ji}—Standard value of horizontal earthquake action of the mass point i produced by vibration mode j (N);

α_j—Seismic influence factor of the natural vibration period of mode j of the electrical equipment (or structure);

γ_j—Modal participation coefficient of mode j;

X_{ji}—Horizontal relative displacement of mass point i of mode j;

k—Number of modes, and it is normally taken as the first three modes.

2 The horizontal earthquake action effects (bending moment, shear stress and axial stress) shall be calculated according to the following formula:

$$S_{\mathrm{H}}=\sqrt{\sum_{j=1}^{k} S_{\mathrm{H}_j}^2} \tag{5.1.6-3}$$

Where, S_{H}—Horizontal earthquake action effect;

S_{H_j}—Effect generated by the horizontal earthquake action of mode j of the electrical equipment (or structure).

5.1.7 If the design basic acceleration of earthquake ground motion is not less than 0.20g, the vertical earthquake action effect shall be included.

5.1.8 For the electrical equipment perpendicular to ground, its nominal vertical earthquake action may be taken as 60% of its nominal horizontal earthquake action, and for the electrical equipment non-perpendicular to ground, its nominal vertical earthquake action may be taken as 70% of the nominal horizontal earthquake action of the electrical equipment perpendicular to the grade.

5.2 Floor dynamic magnification factor

5.2.1 If the electrical equipment is provided with supporting structure, the dynamic magnification effect of the supporting structures shall be considered, the seismic influence factor shall multiply the dynamic magnification factor of the supporting structure.

5.2.2 The supporting structure and the electrical equipment may be seismically qualified as a whole.

5.2.3 For the electrical equipment installed on outdoor low supports, on indoor ground floor or in cave, the dynamic magnification factor of their support structures should not be less than 1.2.

5.2.4 For the electrical equipment installed on indoor 2nd floor and 3rd floor, the dynamic magnification factor of the building shall be equal to 2.0. For the electrical equipment installed on higher floors, the dynamic magnification factor of the building shall be larger than 2.0, and the dynamic magnification factor of the building and earthquake action of electrical equipment may be calculated in accordance with Appendix C of this standard.

5.2.5 The dynamic magnification factor of the components (conservator, radiator and porcelain bushing) on the main body of the power transformer shall be equal to 1.5.

5.3 Power transformers

5.3.1 Aseismatic calculation for the anchor bolts of the power transformers shall be in accordance with the following requirements:

1 Calculation of horizontal earthquake action of the power transformers installed on the ground shall be in accordance with those specified in Section 5.1 of this standard, the seismic influence factor may be the maximum value specified in Table 5.1.2-1 of this standard, and the total mass of the transformer shall include the main body of the transformer, oil, conservator, radiator and the insulating bushing;

2 Calculation of horizontal earthquake action of the power transformers installed on the floor shall be in accordance with those specified in Section 5.2 of this standard, and the fundamental period of the power transformer may be equal to 0.1s;

3 Calculation of stresses of the anchor bolts under both horizontal and vertical earthquake actions shall be in accordance with the following requirements:

1) The tensile stress of the anchor bolts may be calculated according to the following formula:

For aseismatic precautionary intensity equal to 7 degree:

$$\sigma_t = \frac{2F_H H_v - m_{eq} l_b}{n A_s l_b} \tag{5.3.1-1}$$

For aseismatic precautionary intensity larger than 7 degree:

$$\sigma_t = \frac{F_v}{n A_s} + \frac{2F_H H_v - m_{eq} l_b}{n A_s l_b} \tag{5.3.1-2}$$

Where, σ_t—Tensile stress of the anchor bolts (Pa);

F_H—Horizontal earthquake action of the main body of the transformer (N);

F_v—Vertical earthquake action of the main body of the transformer (N);

n—Number of anchor bolts;

A_s—Effective cross-section area of each anchor bolt (m^2);

l_b—Minimum spacing between anchor bolts (m);

H_v—Distance from the half height point of the main body of the transformer to the foundation surface (m);

m_{eq}—Total mass of the equipment (including the main body of the transformer, conservator, radiator and insulating bushing) (kg).

2) The shear stress of the anchor bolts may be calculated according to the following formula:

For aseismatic precautionary intensity equal to 7 degree:

$$\tau_v = \frac{F_H - 0.3 m_{eq}}{n A_s} \tag{5.3.1-3}$$

For aseismatic precautionary intensity larger than 7 degree:

$$\tau_v = \frac{F_H - 0.3(m_{eq} - F_v)}{n A_s} \tag{5.3.1-4}$$

Where, τ_v—Shear stress of the anchor bolts (Pa).

4 Aseismatic calculation for the anchor bolts of the power transformers shall conform to the formulas below:

$$\sigma_t \leqslant [\sigma]_d \tag{5.3.1-5}$$

$$\tau_v \leqslant [\tau]_d \tag{5.3.1-6}$$

Where, $[\sigma]_d$—Design allowable tensile stress of anchor bolts at ambient temperature (Pa), it is equal to 180×10^6Pa for low carbon steel;

$[\tau]_d$—Design allowable shear stress of anchor bolts at ambient temperature (Pa), it is equal to 150×10^6Pa for low carbon steel.

5.3.2 Aseismatic calculation for the cantilever radiator of the transformer shall be in accordance with the following requirements:

1 The horizontal earthquake action of the radiator may be calculated according to the following formula:

$$F_l = \alpha_{max} m_l g \tag{5.3.2-1}$$

Where, F_l—Horizontal earthquake action of the radiator (N);

m_l—Mass of the radiator (kg).

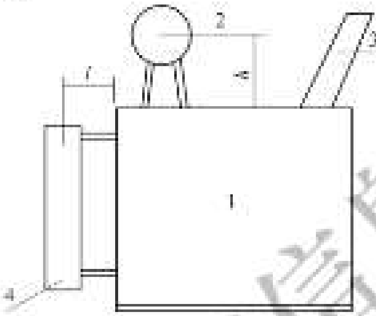

Figure 5.3.2 Simplified outline drawing of transformer

1—Main body of the transformer; 2—Conservator; 3—Porcelain bushing; 4—Radiator

2 In the areas where the aseismatic precautionary intensity is 7 degree and above, the bending stress of the steel pipe connected between the radiator and the main body of the transformer under horizontal earthquake action may be calculated according to the following formula:

$$\sigma_1 = \frac{F_l l D}{2nI} \tag{5.3.2-2}$$

Where, σ_1—Bending stress of the steel pipe connected between the radiator and the main body of the transformer under horizontal earthquake action (Pa);

l—Distance from the center of the radiator to the edge of the main body of the transformer (Figure 5.3.2) (m);

D—OD of the steel pipe connected between the radiator and the main body of the transformer (m);

n—Number of the steel pipes connected between the radiator and the main body of the transformer;

I—Section moment of inertia of one piece of steel pipe (m^4).

3 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, the shear stress of the steel pipe connected between the radiator and the main body of the transformer under horizontal earthquake action may be calculated according to the following formula:

$$\tau_1 = \frac{F_l}{nA} \tag{5.3.2-3}$$

Where, τ_1—Shear stress of the steel pipe connected between the radiator and the main body of the transformer under horizontal earthquake action (Pa);

A—Cross-section area of one piece of steel pipe (m^2).

4 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, the bending stress of the steel pipe connected between the radiator and the main body of the transformer under vertical earthquake action may be calculated according to the following formula:

$$\sigma_2 = \frac{(F_{lv} + m_l g) l D}{2nI} \tag{5.3.2-4}$$

Where, F_{lv}—Vertical earthquake action of the radiator (N);

σ_2—Bending stress of the steel pipe connected between the radiator and the main body of the transformer under vertical earthquake action (Pa).

5 In the areas where the aseismatic precautionary intensity is 8 degree or 9 degree, the shear stress of the steel pipe connected between the radiator and the main body of the transformer under vertical earthquake action may be calculated according to the following formula:

$$\tau_2 = \frac{F_{1v} + m_1 g}{nA} \tag{5.3.2-5}$$

Where, τ_2—Shear stress of the steel pipe connected between the radiator and the main body of the transformer under vertical earthquake action (Pa).

6 The combined stress of the steel pipe connected between the radiator and the transformer may be calculated according to the following formula:

$$\sigma = \sqrt{\sigma_0^2 + 3\tau_0^2} \tag{5.3.2-6}$$

Where, σ—Combined stress of the steel pipe (Pa);

σ_0—Larger value of σ_1 and σ_2 shall be taken (Pa);

τ_0—Larger value of τ_1 and τ_2 shall be taken (Pa).

7 Aseismatic calculation for the steel pipe connected between the radiator and the main body of the transformer shall be in accordance with the following formula:

$$\sigma \leqslant [\sigma] \tag{5.3.2-7}$$

Where, $[\sigma]$—Design allowable stress of the steel pipe connected between the radiator and the main body of the transformer at ambient temperature (Pa), it shall be determined in accordance with Article 3.0.9 of this standard.

5.3.3 Aseismatic calculation for the transformer conservator shall meet the following requirements:

1 The horizontal earthquake action shall be calculated according to the following formulas:

$$F_c = \alpha_{max} m_c g \tag{5.3.3-1}$$

$$F_{cv} = 0.6F_c \tag{5.3.3-2}$$

Where, F_c—Horizontal earthquake action of the transformer conservator (N);

m_c—Mass of transformer conservator (kg);

F_{cv}—Vertical earthquake action of the transformer conservator (N).

2 The bending stress of the transformer conservator under horizontal earthquake action shall be calculated according to the following formula:

$$\sigma_1 = \frac{F_c h}{2Z_1} \tag{5.3.3-3}$$

Where, σ_1—Bending stress of the transformer conservator under horizontal earthquake action (Pa);

h—Distance from the one half position of the conservator to the point where the conservator legs are attached to the main body of the transformer (as shown in Figure 5.3.2) (m);

Z_1—Area moment of inertia of one leg of the conservator at the longitudinal direction of the conservator (m^3).

3 The shear stress of the transformer conservator under horizontal earthquake action shall be calculated according to the following formula:

$$\tau_1 = \frac{F_c}{2A} \tag{5.3.3-4}$$

Where, τ_1—Shear stress of the transformer conservator under horizontal earthquake action (Pa);

A—Cross-section area of one supporting leg of the conservator (m^2).

4 The compression stress of the transformer conservator may be calculated according to the following requirement:

1) In the areas where the aseismatic precautionary intensity is 7 degree, may be calculated according to the following formula:

$$\sigma_z = \frac{m_0 g}{2A} \tag{5.3.3-5}$$

2) In the area where the aseismatic precautionary intensity is above 7 degree, may be calculated according to the following formula:

$$\sigma_z = \frac{F_{sv} + m_0 g}{2A} \tag{5.3.3-6}$$

Where, F_{sv}—Horizontal earthquake action of the transformer conservator (N);

σ_z—Compression stress of the transformer conservator (Pa).

5 The combined stress of the cross section of the transformer conservator legs shall be calculated according to the Formula (5.3.2-6) in Article 5.3.2 of this standard.

6 The combined stress of the transformer conservator legs shall be in accordance with the requirement of the following formula:

$$\sigma \leq [\sigma] \tag{5.3.3-7}$$

Where, σ—Combined stress of the cross section of the transformer conservator legs (Pa);

$[\sigma]$—Design allowable stress of the transformer conservator legs (Pa) at ambient temperature, it shall be determined in accordance with Article 3.0.9 of this standard.

5.4 Vertically installed three-phase reactors

5.4.1 Aseismatic calculation shall be made for the supporting porcelain insulators on each layer of vertically installed three-phase reactors (hereafter shortened as reactor).

5.4.2 Aseismatic calculation for the reactors may be simplified to a three-degree-of-freedom in series model, the mass of each phase reactor shall be taken as the mass of each mass point and shall be located at the center of mass.

5.4.3 The fundamental period of the reactor may be calculated according to the following formulas, and it may be equal to 0.1s for simplified calculation.

$$T_1 = 2\pi\sqrt{\frac{\sum_{i=1}^{3} m_i H_i^2}{\sum_{i=1}^{3} K_i (H_i - H_{i-1})^2}} \tag{5.4.3-1}$$

$$K_i = \frac{12EI_i n_i}{h_i^3} \tag{5.4.3-2}$$

Where, K_i—Lateral rigidity of the supporting porcelain insulator column on layer i (N/m);

E—Modulus of elasticity of the material of the supporting porcelain insulator column (Pa);

I_i—Second axial moment of area of single supporting porcelain insulator column on layer i (m^4);

n_i—Number of supporting porcelain insulator columns on layer i;

H_i—Height of mass point i (m);

h_i—Height of supporting porcelain insulator columns on layer i (m);

m_i—Mass of the mass point i (kg).

5.4.4 The horizontal seismic action of the mass point on each layer of the reactor shall be calculated in accordance with Article 5.1.5 of this standard.

5.4.5 The bending moment at the bases of the supporting porcelain insulator columns on each layer shall be calculated according to the following formulas:

$$M_1 = \sum_{j=1}^{3} F_j H_j \tag{5.4.5-1}$$

$$M_2 = \sum_{j=2}^{3} F_j (H_j - H_1 - h/2) \tag{5.4.5-2}$$

$$M_3 = F_3 (H_3 - H_2 - h/2) \tag{5.4.5-3}$$

Where, M_1, M_2, M_3—Bending moment at the bases of the supporting porcelain insulator columns respectively on layers 1, 2 and 3 (N·m);

h—Height of single phase reactor (m).

5.4.6 The tensile stress and shear stress of the supporting porcelain insulator columns on each layer shall be calculated according to the following formulas:

$$\sigma_{ti} = \frac{1}{n_i A_i}\left(\frac{4M_i}{D_i} - \sum_{j=i}^{3} m_j g\right) \tag{5.4.6-1}$$

$$\tau_i = \frac{\sum_{j=i}^{3} F_j}{n_i A_i} \tag{5.4.6-2}$$

Where, σ_{ti}—Tensile stress at the base of supporting porcelain insulator column on layer i (Pa);

τ_i—Shear stress at the base of the supporting porcelain insulator column on layer i (Pa);

A_i—Effective cross-section area of a single supporting porcelain insulator column on layer i (m^2);

D_i—Diameter of the center circle of the supporting porcelain insulator column on layer i (m).

5.4.7 Aseismatic calculation for the cross section of the supporting porcelain insulator columns on each layer shall be respectively in accordance with those specified in the following formulas:

$$\sigma_{ti} \leq [\sigma] \tag{5.4.7-1}$$

$$\tau_i \leq [\tau] \tag{5.4.7-2}$$

Where, $[\sigma]$—Design allowable tensile stress of the support porcelain insulator column at ambient temperature (Pa), it shall be determined in accordance with Article 3.0.9 of this standard;

$[\tau]$—Design allowable shear stress of the support porcelain insulator column at ambient temperature (Pa), it shall be determined in accordance with Article 3.0.9 of this standard.

5.4.8 The tensile stress and shear stress of the anchor bolts on each layer of the reactor shall be calculated respectively according to the following formulas:

$$\sigma_{bi} = \frac{1}{n_i n_{bi} A_{bi}}\left(\frac{4M_i}{D_{bi}} - \sum_{j=i}^{3} m_j g\right) \tag{5.4.8-1}$$

$$\tau_{bi} = \frac{\sum_{j=i}^{3} F_j - 0.4\sum_{j=i}^{3} m_j g}{n_i n_{bi} A_{bi}} \tag{5.4.8-2}$$

Where, σ_{bi}—Tensile stress of the anchor bolts of the support porcelain insulator columns on layer i (Pa), if the calculated value is less than 0, it shall be equal to 0;

τ_{bi}—Shear stress of the anchor bolts of the support porcelain insulator columns on layer i (Pa), if the calculated value is less than 0, it shall be equal to 0;

n_{bi}—Number of anchor bolts of a single support porcelain insulator column on layer i;

A_{bi}—Effective cross-section area of one anchor bolt of the support porcelain insulator column on layer i (m^2);

D_i—Diameter of the center circle of anchor bolt of the support porcelain insulator column on layer i (m).

5.4.9 Aseismatic calculation for the cross section of anchor bolts of the reactor on each layer shall be respectively in accordance with those specified in the following formulas:

$$\sigma_{bi} \leqslant [\sigma_b] \quad (5.4.9\text{-}1)$$

$$\tau_{bi} \leqslant [\tau_b] \quad (5.4.9\text{-}2)$$

Where, $[\sigma_b]$ Design allowable tensile stress of the anchor bolts at ambient temperature (Pa), it shall be determined in accordance with Article 3.0.9 of this standard;

$[\tau_b]$—Design allowable shear stress of the anchor bolts at ambient temperature (Pa), it shall be determined in accordance with Article 3.0.9 of this standard.

5.5 Circuit breakers and arresters

5.5.1 Aseismatic calculation shall be made for the following locations of circuit breakers and arresters:

1 The porcelain insulator at the base of circuit breaker or arrester;

2 The base of the porcelain insulator above the insulated tie-rod of the arrester with insulated tie-rods.

5.5.2 The fundamental period of circuit breakers and arresters installed on the ground shall be calculated in accordance with the following requirements:

1 The fundamental period of circuit breakers and arresters without insulated tie-rods may be calculated according to the following formulas:

$$T = 1.787\sqrt{\frac{mH^3}{EI\beta}} \quad (5.5.2\text{-}1)$$

$$I = \frac{\pi}{64}(D^4 - d^4) \quad (5.5.2\text{-}2)$$

Where, T—Natural vibration period of the equipment (s);

m—Total mass of the equipment, including all the devices and oil (kg);

H—Total height of the equipment (m);

E—Modulus of elasticity of the materials of porcelain insulators (Pa), it may be equal to 75×10^9Pa;

β—Rigidity reduction coefficient with consideration of factors including node. It may be equal to 0.2 for the circuit breakers and 0.22 for the arresters;

I—Second axial moment of area at the base of porcelain insulator (m^4);

D, d—OD, ID of the porcelain insulator (m).

2 The fundamental period of the arresters with insulated tie-rods shall be calculated according to the following formula:

$$T = 1.835\sqrt{\frac{mH^3}{EI}} \quad (5.5.2\text{-}3)$$

5.5.3 The earthquake action and the seismic bending moment of the circuit breakers and the arresters installed on ground shall be calculated in accordance with the following requirements:

1 The earthquake action and the bending moment of the calculated cross section of arresters without insulated tie-rods and the circuit breakers shall be calculated according to the following formulas:

$$F = \alpha m g \qquad (5.5.3\text{-}1)$$

$$M = F\left(\frac{2}{3}H - h\right) \qquad (5.5.3\text{-}2)$$

Where, F—Earthquake action applied to the arresters without insulated tie-rods and the circuit breakers (N);

M—Bending moment of the calculated cross section (N·m);

α—Seismic influence factor, it shall be determined in accordance with Article 5.1.2 of this standard;

h—Height from the calculated cross section to the base of the equipment (m).

2 The horizontal earthquake action and the bending moment of the calculated cross section of the arrester with insulated tie-rods shall be in accordance with the following requirements:

1) The horizontal earthquake action of the arresters with insulated tie-rods shall be calculated according to the following formula:

$$F = \alpha m g \qquad (5.5.3\text{-}3)$$

2) If the height from the calculated cross section to the base of the equipment, h, is not less than $\frac{5}{8}H$, the bending moment at the location where the tie-rods and arrester are connected shall be calculated according to the following formula:

$$M = F(0.88H - h) \qquad (5.5.3\text{-}4)$$

3) If the height from the calculated cross section to the base of the equipment, h, is less than $\frac{5}{8}H$, but equal to or larger than 0, the bending moment below the location where the tie-rods and arrester are connected shall be calculated according to the following formula:

$$M = F(0.612h - 0.1275H) \qquad (5.5.3\text{-}5)$$

5.5.4 The fundamental period of the circuit breakers and the arresters installed on the supports (Figure 5.5.4) shall be calculated according to the following formulas:

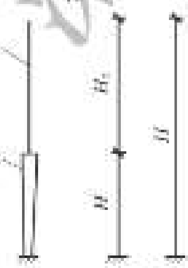

Figure 5.5.4 Calculation of the fundamental period of the electrical equipment installed on support

1—Equipment; 2—Support

$$T = 2\pi\sqrt{\frac{m'}{K}} \qquad (5.5.4\text{-}1)$$

$$K = \frac{\lambda_1}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3}} \qquad (5.5.4\text{-}2)$$

$$K_1 = \frac{3E_1 I_1}{H_1^3} \qquad (5.5.4\text{-}3)$$

$$K_2 = \frac{24E_2 I_2}{H_2^3} \qquad (5.5.4\text{-}4)$$

$$K_1 = \frac{4E_1 I_1}{H_1 H_2 (2H_1 + H_2)} \qquad (5.5.4\text{-}5)$$

Where, m'—Equivalent mass of the system (kg), it may be equal to the total mass of the equipment (including all devices and oil) plus 1/3 of the mass of the support;

K—Lateral rigidity of the system (N/m);

λ_1—Lateral rigidity reduction coefficient, it may be equal to 0.19 for the circuit breakers and 0.22 for the arresters;

E_1—Modulus of elasticity of the support material (Pa);

I_1, I_2—Second axial moment of area of the support and the area of the porcelain insulator (m^4);

H_1, H_2—Height of the support (up to the rim of the cup), and the height of equipment (m).

5.5.5 The bending moment of the calculated cross section of the circuit breaker and the arrester installed on the supports shall be calculated according to the following formula:

$$M = \alpha m' g \left(H_1 + \frac{H_2}{2} - h \right) \qquad (5.5.5)$$

5.5.6 Aseismatic calculation for the circuit breakers and the arresters shall be in accordance with those specified in the following formulas:

$$\sigma = \frac{kM}{W} \leqslant [\sigma] \qquad (5.5.6\text{-}1)$$

$$W = \frac{\pi}{32D} (D^4 - d^4) \qquad (5.5.6\text{-}2)$$

Where, σ—Stress of the calculated cross section of the equipment (Pa);

W—Modulus of section of the calculated cross section (m^3);

D, d—OD, ID of the porcelain insulator (m);

$[\sigma]$—Design allowable stress of the material required for calculation (Pa), it may be equal to 11.2×10^6 Pa for the material of porcelain insulators and equal to 18×10^6 Pa for C25 concrete base at ambient temperature;

k—Unbalance factor, it may be equal to 1.5.

Appendix A Shock-absorbing measures for electrical equipment

A.1 General requirements

A.1.1 The electrical equipment may be provided with shock-absorbing devices for achievement of shock damping performance. Shock-absorbing devices may be rubber dampers, rubber damping pads, bending-shear type, and compression type and shear type lead alloy dampers, etc.

A.1.2 Proper shock-absorbing measures shall be selected based on the construction features, service requirements and natural vibration period of the electrical equipment as well as the site class.

A.1.3 In the areas where the ambient temperature is −15℃ and below in winter, low temperature resistant rubber dampers shall be selected.

A.1.4 After the electrical equipment is installed with dampers, they shall meet the strength, displacement and process requirements.

A.1.5 The shock-absorbing devices should be located at the supports or the connections between the electrical equipment and the foundations/buildings (structures).

A.1.6 The shock-absorbing measures taken shall not interfere with the normal operational functions of the electrical equipment.

A.1.7 After the shock-absorbing devices are installed, they shall be examined on a regular basis, and at least a thorough inspection shall be made whenever the equipment is cleaned and serviced.

A.2 Shock-absorbing measures

A.2.1 Aseismatic calculation for the electrical equipment after shock-absorbing devices are installed may be performed by using the technical parameters of the shock-absorbing devices, and it may also be performed in a way of the maximum combined stress of the original equipment multiplying the stress reduction coefficient. And the stress reduction coefficient shall be determined per Table A.2.1.

Table A.2.1 Stress reduction coefficient

Aseismatic precautionary intensity	Site class			
	I	II	III	IV
7 degree	0.4	0.4	0.5	0.7
8 degree	0.6	0.6	0.8	0.7

A.2.2 The connection conductors between the electrical equipment installed with shock-absorbing devices and other equipment shall be flexible conductor.

A.3 Shock-absorbing measures for arresters

A.3.1 Aseismatic calculation for the arresters installed with rubber damping pads may be made in a way of the maximum stress of the arresters without rubber damping pads multiplying 0.4.

A.3.2 The rubber damping pads of the shock-absorbing devices for the arresters may be installed per the method indicated in Figure A.3.2.

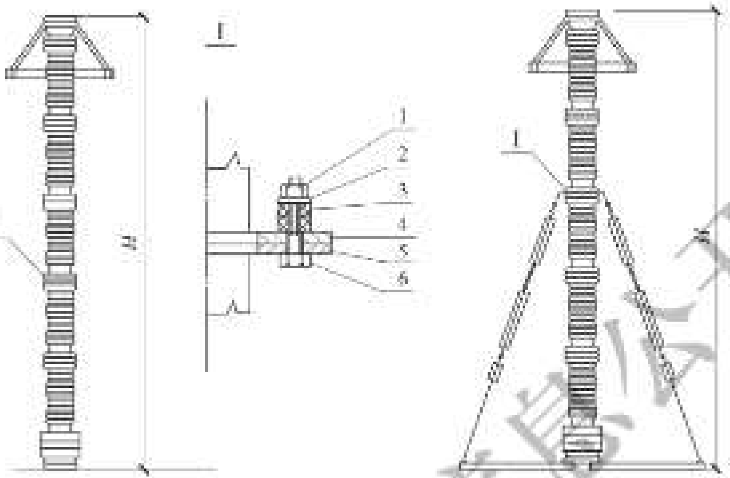

Figure A.3.2 Shock-absorbing device for arrester

1—nut;2—gasket;3—rubber damping pad;

4—upper flange of the porcelain insulator;5—lower flange of the porcelain insulator;6—bolt

A.3.3 For the arrester without insulated tie-rods, if the aseismatic precautionary intensity is 7 degree, double rubber damping pads may be provided onto the bolt of the porcelain insulator flange at the base, and if the seismic precautionary intensity is 8 degree, double rubber damping pads shall be provided onto the bolt of each porcelain insulator flange.

A.3.4 For the arresters with insulated tie-rod, double rubber damping pads shall be provided onto the bolt of each porcelain insulator flange.

A.3.5 The size of rubber damping pad should be 25mm×13mm×8mm (OD×ID×thickness).

A.3.6 After the rubber damping pad is installed, the displacement of the conductor at the top of the arrester shall not be less than 15mm.

A.3.7 The shock-absorbing devices installed for the arresters shall comply with the following requirements:

1 When the rubber damping pads are being installed, the bolt shall be rotated to compress the pads, and the total compression of each group of pads shall be 4mm.

2 If the material of rubber damping pad is butyl rubber, it shall have good damping, heat resistant and aging resistant performance, and shall comply with the current relevant standards of the nation.

Appendix B Aseismatic measures for vertically installed three-phase reactors

B.1 General requirements

B.1.1 The aseismatic measures taken for vertically installed three-phase reactor (Figure B.1.1) shall not impose any impact on the original electrical performance.

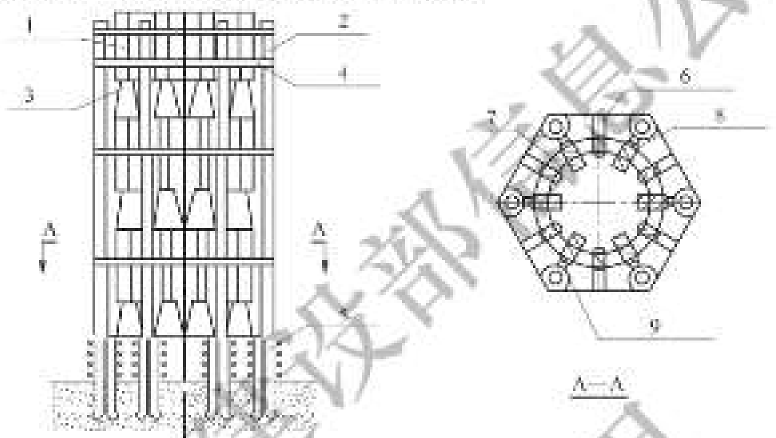

Figure B.1.1 Aseismatic measures taken for vertically installed three-phase reactors

1—reactor; 2—epoxy FRP column; 3—supporting porcelain insulator; 4—circumferential fastening steel strip; 5—bored reinforcement steel pipe; 6—epoxy FRP spacer; 7—rod; 8—reactor column; 9—epoxy FRP pad

Note: the epoxy FRP pad and epoxy FRP column must be integrally connected and fastened with the reactor.

B.1.2 When epoxy FRP is used as the main material, it shall comply with the following requirements:

1 Dynamic performance test shall be provided for the epoxy FRP products as per relevant standards, and the test items shall include tensile strength, bending strength, compression strength, shear strength, density and modulus of elasticity based on the stresses applied to epoxy FRP materials on a specific case basis.

2 AC withstand voltage test shall be made for epoxy FRP insulation performance. The main electrical performance parameters shall meet the following requirements:

1) The coefficient of internal resistance shall be larger than $10^{6}\Omega$/mm.

2) The disruptive voltage between the parallel layers (at 90°C±2°C and in an electrode center to center distance of 15mm) shall be larger than 15kV.

3 When the epoxy FRP pipes are delivered to site, at least 1 piece shall be sampled from each lot for AC power frequency withstand voltage test.

B.1.3 After aseismatic measures are taken and the reactors are put into operation, the following requirements shall be complied with:

1 Steel strip to earth floating potential shall not be larger than 2V, and the temperature variation of the fastening steel strip shall be closely monitored.

2 After the reactors are put into operation for 4 weeks, heat run test should be made at the rated voltage and maximum load current (approximate to or equal to the rated current of the reactor).

B.1.4 The length of epoxy FRP column shall be calculated by the equation below:

$$L = 3H + h - 0.1 \tag{B.1.4}$$

Where, L—Length of epoxy RFP column (m);

H—Height of single phase reactor (m);

h—Height of the reactor foundation (m).

B.1.5 The epoxy FRP material shall be provided with mechanical performance test report, and the test report shall include the test items and test method.

B.1.6 AC withstand voltage test shall be made for the epoxy FRP used as Class B insulation reinforcing material for reactor, and the test voltage and test duration shall conform to Table B.1.6.

Table B.1.6 Insulation test voltage and test duration

Voltage rating (kV)	Test voltage (kV)	Test duration (min)
6	32	AC power frequency test, 1
10	42	AC power frequency test, 1

B.1.7 The coefficient of internal resistance of epoxy FRP shall be larger than 10^{7} (Ω/mm), the disruptive voltage between the parallel layers (at 90°C±2°C and in an electrode center to center distance of 15mm) shall be larger than 15kV, the manufacturers shall carry out these tests and provide test reports.

B.1.8 After the epoxy FRP columns are delivered to site, samples shall be taken from each lot for AC power frequency withstand voltage test, at least 1 piece of column shall be sampled from each group, and the test items shall comply with the following requirements:

1 AC withstand voltage test shall be made for the epoxy FRP columns, and the test criteria shall conform to Table B.1.6.

2 After the reactors are reinforced and painted, conventional AC withstand voltage test shall be made for the entire reactors.

3 After Aseismatic measures are taken and the reactors are put into operation, the fastening steel strip to earth voltage shall be measured, and the voltage shall be less than 2V.

B.2 Construction requirements

B.2.1 The ID of the steel pipe selected shall be close to the OD of epoxy FRP pipe, and the lower part of epoxy FRP pipe shall be inserted into the steel pipe. The bottom of the epoxy FRP pipe and the horizontal line shall be on one same plane, three or four M16 bolts shall be used for connection, the spacing between the bolts may be 3 to 10 times the diameter of the bolt holes, and the buried depth shall be larger than 0.3m. After the reinforcing steel pipe is bolted to the epoxy FRP pipe, the lower part of the pipe shall be buried into the foundation and grouted with concrete (Figure B.2.1). All the reinforcing steel pipes shall be provided with good earthing provisions.

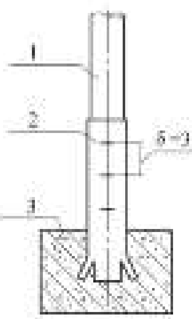

Figure B.2.1 Buried steel pipe

1—epoxy FRP pipe; 2—buried reinforced steel pipe; 3—concrete foundation

B.2.2 The epoxy FRP pipe, circumferential fastening steel strip and the pad shall be securely fixed together (Figure B.2.2) by using M16 or M12 bolts. The pad may be phenol resin laminate or transformer oil immersed hard wood with moisture proof coating.

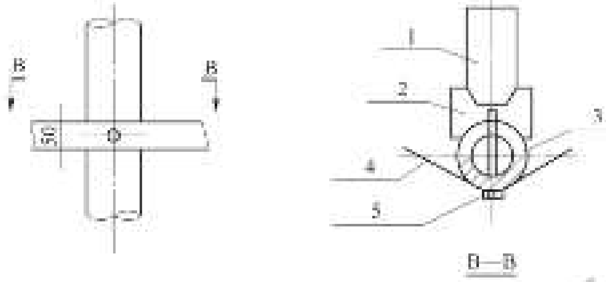

Figure B.2.2 Connection of epoxy FRP pipe, circumferential fastening steel strip and pad

1—reactor supporting porcelain insulator column; 2—phenol resin laminate; 3—epoxy FRP pipe; 4—circumferential fastening steel strip; 5—bolts

B.2.3 Where the reactor is set on the concrete floor, the combined steel pipe shall be welded to the base. The base shall be securely fixed to the floor by using four M20 bolts, and double nuts or single nut plus spring washer shall be used (Figure B.2.3).

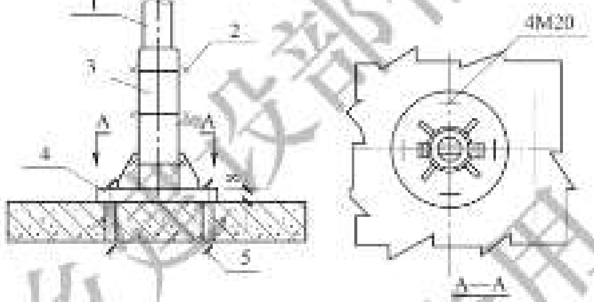

Figure B.2.3 Connection between combined steel pipe and floor

1—insulating epoxy FRP pipe; 2—bolt; 3—reinforcing combined steel pipe; 4—base; 5—bolts

B.2.4 The circumferential fastening steel strip should be 50mm×5mm low carbon steel strip or austenitic stainless steel strip. The steel strip may be cut into 2 or 3 segments, and M16 bolts are used to circumferentially fasten them. The steel strips shall closely contact to the reactor to enable the reactor and the reinforcing frame to form an integral unit. The steel strip should be arranged to the mass point of each phase reactor, and two circles of circumferential fastening steel strips shall be installed near to the mass point of one phase reactor at the top.

B.2.5 Each circumferential fastening steel strip shall consist of several segments, the spacing between two segments should be 4mm—10mm, and epoxy FRP spacer shall be used to connect the segments (Figure B.2.5).

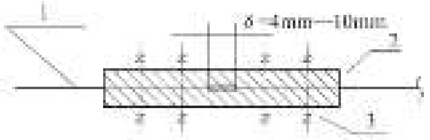

Figure B.2.5 Connection of circumferential fastening steel strips

1—circumferential fastening steel strip; 2—epoxy FRP spacer; 3—bolts

Appendix C Calculation of earthquake action of electrical equipment on floor

C.0.1 The dynamic magnification factor of the floor on which electrical equipment is installed shall be determined according to those specified in Figure C.0.1. When determining the fundamental period of the electrical equipment, the building (structure) may be assumed as the rigid foundation on which the electrical equipment is installed.

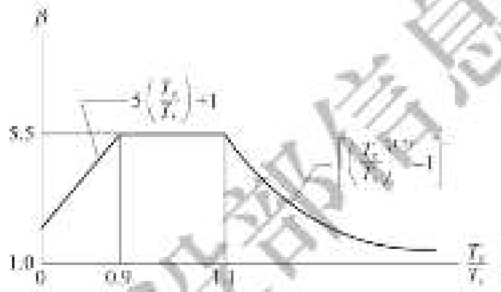

Figure C.0.1 Floor dynamic magnification factor curve

β—the floor dynamic magnification factor; T_s—the fundamental period of the building (structure) to support the electrical equipment (s); T_e—the fundamental period of the electrical equipment (s)

C.0.2 When determining the natural vibration period of the building (structure) to support the electrical equipment, the mass of the floor shall include the mass of both the electrical equipment and its attachments on the floor. If it is difficult to determine the nominal mass of the body of the floor, it may be equal to 100kg/m²—150kg/m² for steel building (structure) and 450kg/m²—600kg/m² for reinforced concrete building (structure).

C.0.3 The fundamental period of the building (structure) should be calculated in accordance with the following requirements:

1 The fundamental period of steel building (structure) may be calculated according to the following formula:

$$T_s = 0.03H_s \qquad (C.0.3\text{-}1)$$

Where, H_s—Total height of building (structure) (m).

2 The fundamental period of reinforced concrete building (structure) may be calculated according to the following formula:

$$T_s = 0.075H_s^{3/4} \qquad (C.0.3\text{-}2)$$

3 The fundamental period of brick-concrete building (structure) may be calculated according to the following formula:

$$T_s = 0.05H_s^{2/3} \qquad (C.0.3\text{-}3)$$

C.0.4 Calculation of horizontal earthquake action of the electrical equipment on the floor shall be in accordance with the following requirements:

1 The multi-floor building (structure) to support the electrical equipment may be simplified into a multi-degree-of-freedom system for aseismatic calculation (Figure 5.1.5 of this standard);

2 The acceleration factor of floor i shall be calculated according to the following formula:

$$\alpha'_{u}=\frac{F_i}{m_i g} \quad (C.0.4\text{-}1)$$

Where, α'_{u}—Acceleration factor of floor i;

F_i—Nominal horizontal earthquake action of floor i (N).

3 The horizontal seismic influence factor of the electrical equipment on floor i shall be calculated according to the following formula:

$$\alpha_{u}=\beta\alpha'_{u} \quad (C.0.4\text{-}2)$$

Where, α_{u}—Horizontal seismic influence factor of the electrical equipment on floor i.

4 The nominal horizontal earthquake action of the electrical equipment on floor i shall be calculated according to the following formula:

$$F_{HK}=\alpha_{u}m_{eq}g \quad (C.0.4\text{-}3)$$

Where, F_{HK}—Nominal horizontal earthquake action of the electrical equipment on floor i (N).

5 If the nominal horizontal earthquake action calculated for the electrical equipment installed on the floor is less than the nominal horizontal earthquake action of the electrical equipment assumed to be installed on the ground, the nominal horizontal earthquake action of the electrical equipment assumed to be installed on the ground shall be used.

Explanation of wording in this standard

1 Words used for different degrees of strictness are explained as follows in order to mark the differences in implementing the requirements of this standard.

1) Words denoting a very strict or mandatory requirement:

"Must" is used for affirmation, "must not" for negation.

2) Words denoting a strict requirement under normal conditions:

"Shall" is used for affirmation, "shall not" for negation.

3) Words denoting a permission of a slight choice or an indication of the most suitable choice when conditions permit:

"Should" is used for affirmation, "should not" for negation.

4) "May" is used to express the option available, sometimes with the conditional permit.

2 "Shall comply with..." or "shall meet the requirements of..." is used in this standard to indicate that it is necessary to comply with the requirements stipulated in other relative standards and codes.