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(Reaffirmed 1997)

भारतीय मानक

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(पहला पुनरीक्षण)

Indian Standard

CRITERIA FOR DESIGN OF GENERATOR FOUNDATION FOR HYDROELECTRIC POWER STATIONS

(First Revision)

UDC 621·311·21-217

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 1992

Price Group 3

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydroelectric Power House Structures Sectional Committee had been approved by the River Valley Division Council.

The generator foundation of a hydro-power station takes various forms depending mainly upon the shaft arrangement. In the case of vertical shaft generator, its foundation is located almost directly over the spiral casing. For horizontal shaft generator, the foundation is in the form of rectangular block with a recess in the middle for housing the air coolers. Design of foundation of vertical generator comparatively is more complicated as it involves configuration comprising more structural elements as against that of the horizontal generator which generally has mass concrete foundation.

It is virtually impossible to deal with all possible variations in generator foundation arrangement. Hence use of general procedures described in this standard should be based on sound engineering judgement of the design.

This standard was first published in 1974. This revision has been taken up in the light of the comments received from the members. The major modifications made in this first revision are as follows:

a) The hydraulic thrust has been included under necessary data.

b) Important design considerations have been included.

c) A separate paragraph on block-outs is included.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CRITERIA FOR DESIGN OF GENERATOR FOUNDATION FOR HYDROELECTRIC POWER STATIONS

(First Revision)

1 SCOPE

This standard deals with the guidelines and criteria for design of generator foundations in hydroelectric power stations.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
456 : 1978	Code of practice for plain and reinforced concrete (*third revision*)
800 : 1984	Code of practice for general construction in steel (*second revision*)
1889 : 1984	Criteria for earthquake resistant design of structures (*fourth revision*)
2974 (Part 3) : 1975	Code of practice for design and construction of machine foundations : Part 3 Foundations for rotary type machines (medium and high frequency) (*first revision*)

3 NECESSARY DATA

3.1 The following information should be finalized by the structural engineer in consultation with the electrical engineer, mechanical engineer and generator manufacturer:

a) A detailed diagram showing plan and section of generator and its foundations;

b) A detailed drawing showing sizes and location of all anchor bolts, pipe sleeves, pockets, bus ducts, embedded parts, access ways, etc;

c) A detailed loading diagram indicating points of application of all loads and forces considered in foundation design as given in **5.** In the diagram not only the load but also the location direction and areas over which these loads will be distributed should be indicated;

d) The complete weight of the machine as well as separate weights of rotating and stationary parts;

e) Hydraulic thrust;

f) The capacity of rated output of the machine;

g) The operating and runaway speed of the machine; and

h) Maximum rise in temperature of air surrounding the machine.

4 GENERATOR FOUNDATION ARRANGEMENT

4.1 The generator consists of stationary and rotating parts. The stationary parts mainly comprise of wound stator, top and bottom brackets housing thrust and guide bearings. The rotating parts include generator rotor, (spider : rim and field system) exciter armature and permanent magnet and generator rotor.

4.1.1 In a vertical shaft machine, wound stator and bottom bracket directly rest on the foundations. Top bracket rests on stator top. The weight of the rotating parts of the generator as well as of turbine and hydraulic thrust is transmitted through thrust bearing bracket. Guide bearings are provided for maintaining the alignment of the shaft.

In case of horizontal shaft generator, the stator and the rotor generally rest on a common bed plate through pedestal bearings.

4.1.2 Generators are classified mainly in three categories depending upon the location of the thrust and guide bearing as follows:

a) Umbrella type in which thrust bearing and one guide bearing are below the rotor;

b) Semi umbrella type in which thrust bearing and lower guide bearing is below the rotor and one guide bearing is above the rotor, called upper guide bearing; and

c) Suspension type in which thrust bearing is located over the rotor and one guide bearing is above and another below the rotor; the one above is called upper guide bearing and the other one as lower guide bearing.

4.1.3 Generator foundations are designed keeping in view the above categories. These comprise lower bracket support, stator support and barrel/housing of steel or concrete. Lower bracket and stator supports may be continuous

circular or polygonal rings or in form of number of raised pedestals and lower bracket foundation may also be continuous or discontinuous cantilever. The barrel/housing may be constructed in cast-in-situ reinforced concrete or in pre-cast steel framed reinforced/prestressed concrete units properly secured to each other or in steel.

4.2 Generator Foundation Types

The shape and configuration of generator foundation largely depends upon: (a) the shaft arrangement, whether the shaft is vertical or horizontal, and (b) location of the thrust bearing. The details of foundations, however, may also vary depending upon the design and configuration of the equipment. For the purpose of this standard, the generator foundation is broadly classified under the following categories:

a) RCC polygonal or circular foundation with thrust bearing on top of stator and provided with either RCC or steel generator housing (*see* Fig. 1).

b) RCC polygonal or circular foundation with combined thrust and guide bearing located below the rotor (*see* Fig. 2).

c) Steel pit liner cylindrical or truncated cone shape independent of surrounding concrete (*see* Fig. 3).

d) RCC frame with columns/walls and beams;

e) RCC dome (*see* Fig. 4).

f) RCC foundation for horizontal shaft arrangement (*see* Fig. 5).

5 SOME IMPORTANT DESIGN CONSIDERATIONS

5.1 Special care should be taken to avoid the damage to foundations against vibrations.

5.2 In case of use of horizontal jacks for transferring the load through the thrust bearings at the top of the generator to the barrel around location of the jacks. This portion should be designed as a ring to take hoop tension, moments and shears for worst combination of loads during normal running of machines, at the time of erection and at the time of double short circuit of the rotor windings.

6 LOADS AND FORCES

6.1 The generator foundation is to transfer static as well as rotating forces due to stationary and rotating parts. Rotating parts generate torsional as well as radial forces. In case of umbrella/semi-umbrella machines, these static and dynamic forces are transferred down to sub-structure mass concrete through lower bracket resting on the lower bracket support end through upper bracket (lower as well as through thrust bearing in case of suspension type machines) resting on the stator support on the stator foundation, which also take the static load.

6.2 The loads and forces given in **6.2.1** to **6.2.11** should be considered for designing the generator foundation. Some of the loads listed below may not be applicable to any particular generator foundation. Any other load peculiar to any foundation arrangement and recommended by the turbine or generator manufacturers should be considered. Final design loads should be established through close co-ordination with the manufacturers and electrical and mechanical engineers.

6.2.1 Dead loads from civil works.

6.2.2 Live load on floors transmitted to the generator foundation.

6.2.3 Vertical load on stator sole plate which may comprise the following:

a) Weight of permanent magnet generator, wherever applicable;

b) Weight of pilot and main exciter, wherever applicable;

c) Weight of thrust bearing, generator, rotor, shaft, turbine rotating parts and hydraulic thrust (for suspended type generators only);

d) Weight of top guide bearing;

e) Weight of top bracket, stator flooring and stator; and

f) Any other load due to equipment on the generator foundation, recesses in the pit liner housing gate operating servomotor, etc.

6.2.4 Vertical load on lower bracket, which may comprise the following:

a) Weight of lower bracket, brakes and jacks;

b) Load while lifting the rotor on jacks, wherever applicable; and

c) Weight of thrust bearing generator rotor, shaft, turbine rotating parts and hydraulic thrust (not applicable for suspended type generator).

6.2.5 Torsional load, which may comprise the following:

a) Maximum tangential force at the stator sole plate due to short circuit in stator winding; and

b) Tangential force at lower bracket sole plate due to braking or bearing friction torque, wherever applicable.

6.2.6 Radial force, which may comprise the following:

a) Radial force on stator sole plate/RCC generator housing due to one sided magnetic attraction; and

b) Radial force on lower guide bearing due to one sided magnetic attraction.

6.2.7 The loads on a horizontal shaft generator on a common bed plate may comprise the following:

a) Weight of stator, rotor, pedestal bearing and bed plate;

b) Weight of overhang exciter and runner;

c) Maximum vertical force due to short circuit in stator;

d) Bearing reaction due to unbalanced jets; and

e) Axial hydraulic thrust.

6.2.8 *Forces Due to Eccentricity in Rotating Parts*

Although each generator should be well balanced, yet certain unbalanced forces, caused by the fact that the centre of gravity of rotating parts may not exactly coincide with the axis of rotation, which induce foundation vibrations, should be accounted for in the design of foundation in consultation with the manufacturers.

6.2.9 *Vibrations Due to Unequal Ground Settlement*

Vibrations may also be induced due to change in verticality of the shaft as a result of unequal ground settlement which may take place over time during the course of operation.

6.2.10 The generator foundation should be designed for seismic loads in accordance with IS 1893 : 1984.

6.2.10.1 In case of generator foundation located in seismic zones the sole plates for stator and bottom brackets should be anchored not only vertically and transversely but also radially.

6.2.11 *Forces Due to Temperature and Shrinkage*

Forces due to temperature variation and shrinkage in generator foundation should be catered for in the design. The temperature variation should be taken as the difference of temperature developed during the machine in action from that of average surrounding tempeature. However, a minimum of 25 mm bars at 30 cm centre-to-centre should be provided on both the faces in both directions.

6.2.12 All possible combinations of forces and loads should be examined for evaluation of critical moments, shears and thrust on the generator foundation. However, the maximum radial force due to one sided magnetic attraction caused due to short-circuiting of half of the rotor poles need not be considered alongwith seismic loads.

7 EFFECT OF VIBRATIONS

7.1 To take the effects of vibrations into account guidance may be taken from IS 2974 (Part 3) : 1975. Further in a hydro-electric power station foundation, should be checked against the effects of runaway speed.

8 BLOCK-OUTS

8.1 Efforts should be made to provide minimum possible number of block-outs in the concrete barrels. For supporting purposes steel plate/flat embedments be used for welding the supporting brackets instead of providing block-outs for grouting bolts. For making block-outs wherever unavoidable, thermocole form-work be used which gets dissolved in petrol instead of wooden one. Provision of block-outs for tightening the bolts at both the ends be made for effective installation of the bolts, wherever possible, well designed non-shrink grouts be used for grouting of the bolts.

9 MATERIALS AND PERMISSIBLE STRESSES

9.1 Reinforced Concrete

It should conform to IS 456 : 1978.

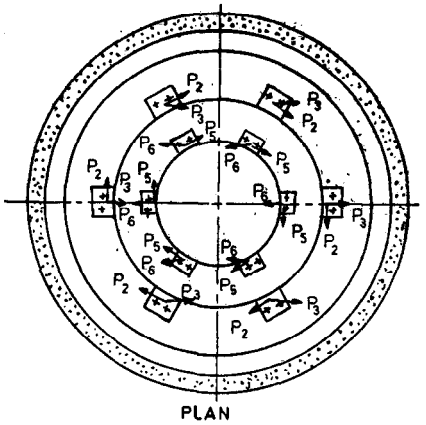
9.2 Structural Steel

It should conform to IS 800 : 1984.

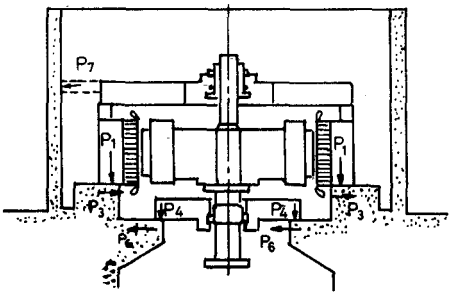
9.3 Permissible Stresses

Permisible stresses should be taken in accordance with IS 456 : 1978 and IS 800 : 1984.

9.3.1 Concrete and steel stresses may be suitably reduced to take care of indeterminacy of loads/structure and dynamic forces.



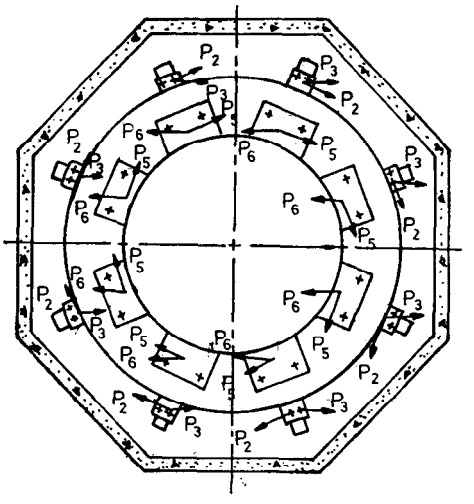
PLAN



SECTIONAL ELEVATION

P_1 = vertical force on stator sole plate
P_2 = tangential force on stator sole plate
P_3 = radial force on stator sole plate (direction assumed; may act in any direction in horizontal plane)
P_4 = vertical force on lower bracket sole plate
P_5 = tangential force on lower bracket sole plate
P_6 = radial force on lower bracket sole plate
P_7 = radial force on RCC generator housing (present only if bracing provided between housing and top bracket)

FIG. 1 RCC CIRCULAR GENERATOR FOUNDATION WITH THRUST BEARING ON TOP OF STATOR



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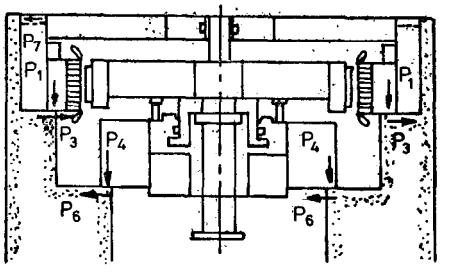

SECTIONAL ELEVATION

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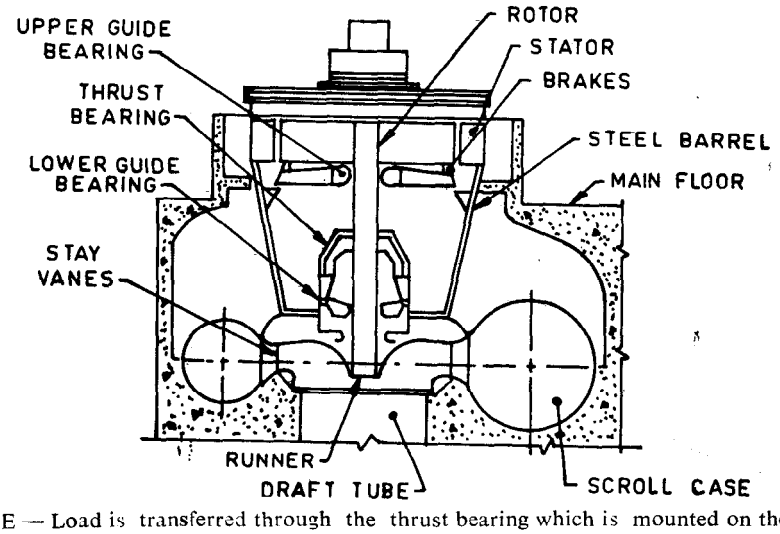
P_3 = radial force on stator sole plate (direction assumed; may act in any direction in horizotal plane)
P_4 = vertical force on lower bracket sole plate
P_5 = tangential force on lower bracket sole plate
P_6 = radial force on lower bracket sole plate
P_7 = radial force on RCC generator housing (present only if bracing provided between housing and top bracket)

FIG. 2 RCC OCTAGONAL GENERATOR FOUNDATION WITH COMBIND THRUST AND GUIDE BEARING LOCATED BELOW THE STATOR



NOTE — Load is transferred through the thrust bearing which is mounted on the barrel.

FIG. 3 STEEL PIT LINER TRUNCATED CONE SHAPED FOUNDATION WITH THRUST BEARING SUPPORTED ON TURBINE TOP COVER

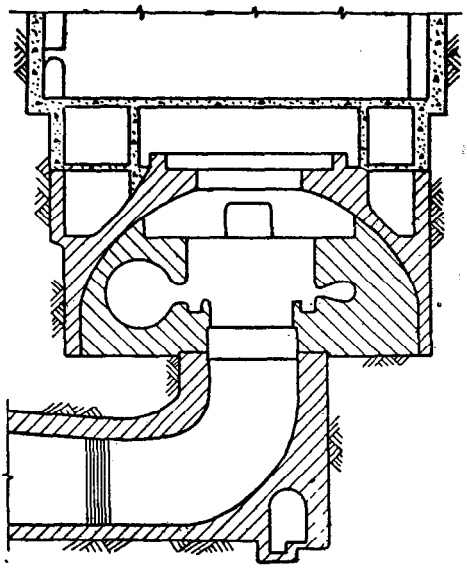
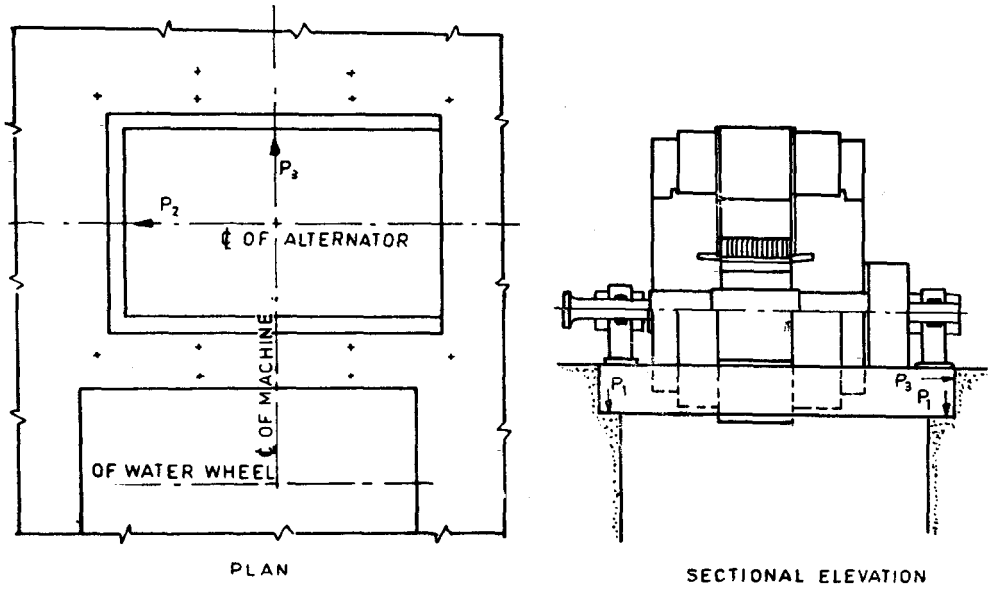


FIG. 4 DOME TYPE GENERATOR FOUNDATION



P_1 = vertical load
P_2 = horizontal component of bearing reaction (direction assumed)
P_3 = axial hydraulic thrust (direction assumed)

FIG. 5 RCC GENERATOR FOUNDATION FOR SHAFT ARRANGEMENT

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