

IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications

Sponsor
**Energy Development and Power Generation Committee
of the
IEEE Power Engineering Society**

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IEEE Standards Board

IEEE Std 1095-1989, *IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications*, describes installation procedures for synchronous generators and generator/motors rated 5000 kVA and above to be coupled to hydraulic turbines having vertical shafts.

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Foreword

(This Foreword is not part of IEEE Std 1095, IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications.)

Large hydraulic turbine-driven generators are shipped as components and completely assembled and installed at the site. The installation, therefore, becomes a continuation of the manufacturing process, and many of the operations involved are those that are normally performed in the factory on smaller generators. Close tolerances must be maintained in the fit and alignment of the various parts. The use of proper installation procedures is essential to achieve satisfactory operation of the unit.

This Guide incorporates much of the information previously found in the National Electrical Manufacturers Association (NEMA) publication MG 5.2, Installation of Vertical Hydraulic-Turbine-Driven Generators and Reversible Generator/Motors for Pumped Storage Installations. MG 5.2 was originally issued in 1972 and revised in 1975 and 1977. NEMA sponsorship was withdrawn and MG 5.2 was rescinded in September, 1982.

In 1985 the Energy Development and Power Generation Committee of the IEEE Power Engineering Society agreed to sponsor the Guide, and the Hydroelectric Power Subcommittee undertook the task of reviewing, revising, and reissuing it.

The IEEE Std 1095, IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications Working Group wishes to acknowledge the contributions made to the guide by R. D. Handel and J. M. Quigley.

At the time this Guide was approved, the members of the Working Group were as follows:

David J. Parker, *Chair*

F. L. Brennan
D. L. Evans

P. S. Johrde
D. G. McLaren

M. S. Pierce
D. H. Thomas

The Energy Development and Power Generation Balloting Committee, which approved this guide for submission to the IEEE Standards Board, had the following membership:

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I. B. Berezowsky
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J. E. Stoner, Jr.
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1. Introduction and Scope

The procedures for installation, described in this Guide, apply to all types of synchronous generators and generator/motors rated 5000 kVA and above to be coupled to hydraulic turbines or hydraulic pump/turbines having vertical shafts. All references made in this Guide to “generators” apply equally to “generator/motors.”

2. References

Definitions, characteristics, and test methods not specifically covered in this Guide should comply with the following documents insofar as they are applicable:

- [1] ANSI C50.5-1955, Rotating Exciters for Synchronous Machines.
- [2] ANSI C50.10-1977, American National Standard General Requirements for Synchronous Machines.¹
- [3] ANSI C50.12-1982, American National Standard Requirements for Salient-Pole Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications.
- [4] ANSI/IEEE Std 113-1985, Guide on Test Procedures for DC Machines.
- [5] ANSI/IEEE Std 115-1983, IEEE Guide: Test Procedures for Synchronous Machines.²
- [6] ANSI/IEEE Std 810-1987, Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Runout Tolerances.
- [7] IEEE Std 43-1974, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

²ANSI/IEEE publications can be obtained from ANSI or the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

3. Tools and Facilities

3.1 General

In general, the erector should have the complement of necessary tools and materials ready for use prior to the start of installation. Considerable time and money can be lost if these items are not ready when needed. The responsibility for the supply of erection tools and materials falls into the following main categories:

- 1) Those supplied by the erector
- 2) Those supplied by the manufacturer
- 3) Those supplied by the customer

The following subsections will briefly describe these categories and will act as a guide for a typical installation. It is not intended that the lists be all-inclusive.

3.2 Erection Contractor-Supplied Tools

The tools and erection materials required for erection of a hydro unit are varied and numerous. The list below is indicative of the required items to be supplied by the erector.

- 1) Portable power tools
- 2) Stationary power tools
- 3) Sets of large wrenches, ratchets, slugging, and impact wrenches
- 4) Jacks and hydraulic rams
- 5) Sledgehammers and air hammers
- 6) Pipe bending and threading equipment
- 7) Welding and burning equipment
- 8) Soldering and brazing equipment
- 9) Manual and small power hoists
- 10) Jib crane for building the rotor rim and positioning the field pole assemblies
- 11) Light rigging equipment
- 12) Miscellaneous consumable items
- 13) Stator winding tools
- 14) Precision measuring tools
- 15) Electrical test equipment, including high-potential test sets, kelvin bridge, ohmmeter, megger (500, 1000, 2500 V ranges), voltmeters and ammeters

Craft labor groups are to have personal hand tools available.

3.3 Manufacturer-Supplied Tools

Certain tools will be called for in the customer specification and will be supplied as part of the contract. To be sure of the supply of these tools, the erector should contact the manufacturer and the customer. In most cases, these tools become the property of the customer and are left in good condition after the installation is complete:

- 1) Shaft, rotor, and stator lifting devices
- 2) Slings of proper length and size for the major lifting operations
- 3) Rotor erection pedestal
- 4) A plate for supporting the shaft in a vertical position. The plate is anchored in the assembly area concrete floor or in a pit of the proper depth to bring the rotor to a convenient distance above the floor.
- 5) Pole and coil lifting device
- 6) Thrust-bearing removal equipment
- 7) A set of special wrenches and tools

The manufacturer will, in some instances, supply the erector with special erection tools. These tools are to be agreed upon with the customer prior to the start of erection, preferably during contract negotiations, and are not usually considered as part of the normal erection equipment.

3.4 Customer-Supplied Materials, Services, and Facilities

The customer often supplies various erection materials, services, and facilities for the erector. The customer specification will often spell out definite items that will be furnished. The specific responsibilities of each party should be checked for every job. Some typical items are as follows:

- 1) Use of powerhouse cranes and crane-lifting beams
- 2) Supply of a crane operator
- 3) Compressed air
- 4) Water
- 5) Electric power
- 6) Office space and administrative areas
- 7) First-aid equipment
- 8) Living accommodations for certain people
- 9) Oil and oil filtering equipment for bearings
- 10) Storage space for erection tools and equipment
- 11) Grout
- 12) Certain instrumentation
- 13) Erection pedestal soleplates
- 14) Assembly areas
- 15) Security clearance for power plant access

4. Personnel

It is essential to have a crew of skilled workers with sufficient helpers and a supervisor experienced in the installation of vertical hydraulic turbine-driven generators. In addition to electricians and mechanics, workers skilled in pipe fitting, welding, rigging, and coil winding are usually needed.

In cases where the generator manufacturer is given the job of installing the equipment that he furnishes, he will provide a supervisor and all other personnel needed. Otherwise, it is recommended that one of the generator manufacturer's field representatives be employed to provide technical direction of the installation. The representative's familiarity with the construction of the generator and experience in the installation of similar machines are valuable assets.

Close cooperation between the purchaser, the generator manufacturer, exciter manufacturer, turbine manufacturer, governor manufacturer, and any installation contractors involved is necessary to assure proper installation in the most efficient manner. Agreement of the general procedures to be followed should be reached before actual erection begins.

5. Generator Construction

The following paragraphs give a brief description of the construction features of vertical hydraulic turbine-driven generators that have an important bearing on their installation.

5.1 General Arrangement

The basic elements of the generator are the stator (frame, magnetic core, and windings), rotor (shaft, thrust block, spider, rim, and poles with windings), thrust bearing, one or two guide bearings, upper and lower brackets (for the

support of bearings and other parts), and soleplates, which are bolted to the foundation and form supports for the stationary parts of the machines. Other components may include a direct-connected exciter or starting motor, rotor brakes or combined brakes and jacks, foundation bolts, platform, stairway and handrails, and an air-discharge housing or a totally enclosed ventilating system with surface air coolers.

The thrust bearing can be located above or below the rotor. When only one guide bearing is utilized, it is normally located near the thrust bearing. When two guide bearings are used, one is located above and one below the rotor. A generator with the thrust bearing located above the rotor is referred to as a suspended generator (see Fig 1). A generator with the thrust bearing and a single guide bearing below the rotor is referred to as an umbrella generator (see Fig 2). An umbrella generator with a second guide bearing is referred to as a modified umbrella generator (see Fig 3).

The upper bracket is supported from the stator frame and occasionally requires radial restraint by the generator enclosure. On small generators with their thrust bearing above the rotor, the lower bracket may be integral with or bolted to the stator frame. Otherwise, the lower bracket is supported on its own set of soleplates.

5.2 Stator Construction

The stator frame is usually fabricated from steel plate. Small-diameter stators can be shipped in one piece with the core stacked and the winding installed at the factory. Larger-diameter stators are sectionalized for shipping purposes, the number of sections depending upon shipping limitations, and the sections bolted or welded together at the site.

The sections may be stacked and wound at the factory or at the site, depending on preference or site requirements. If wound at the factory, the coils or bars adjacent to the splits may be shipped separately and the winding completed at the site.

Soleplates, which may have provision for levelling and centering, are grouted into the foundation. On larger diameters, provision is made to permit radial movement between the frame and the soleplates to accommodate thermal effects.

The stator core is composed of electrical grade steel laminations treated with insulating enamel and stacked on keybars or core studs attached to the frame. The laminations are clamped in place by means of finger and flange assemblies, with the required clamping pressure applied and maintained with core studs.

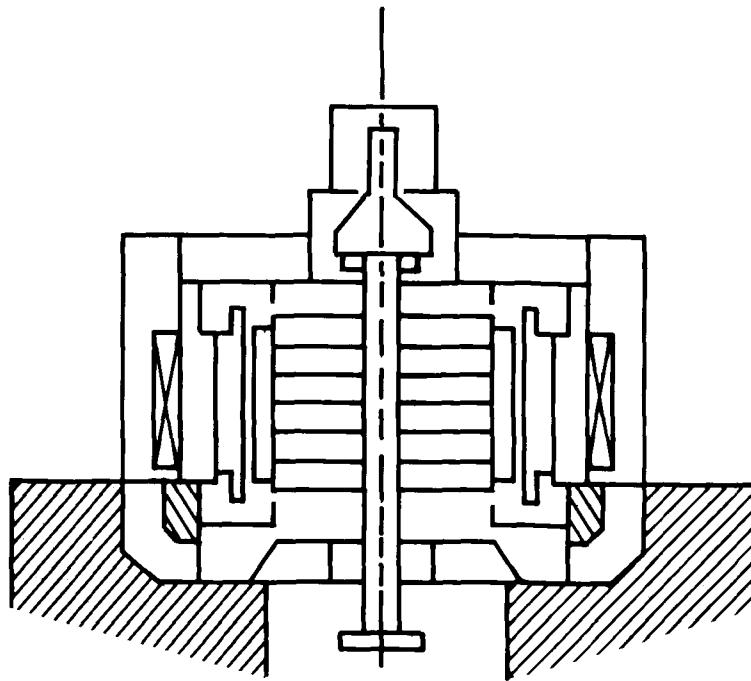


Figure 1—Suspended Generator

The stator winding may consist of single- or multi-turn coils or half-turn bars. Double-layer windings, having two coil sides per slot, are most commonly used. The coils or bars are secured in the stator slots by wedges driven in grooves located at the top of the slots and by side-packing provided separately or integrally with the coil or bar. End windings are braced to restrain movement due to short circuits and to prevent possible downward movement of the stator coils or bars. Temperature detectors are generally installed between coils in a selected number of slots to indicate the temperature of the winding during operation.

5.3 Rotor Construction

The rotor of a small low- or medium-speed generator has a spider, which is generally shrunk on and keyed to the shaft. This spider is usually fabricated such that the hub, web, and rim are a single piece. The rim is a solid steel ring to which the poles are attached by bolts, studs, or dovetails.

Large low- and medium-speed machines have a fabricated spider with a separate rim, which is built up of segmental steel laminations bolted together to form one or several homogeneous rings. This rim is free to expand without constraint from the spider, but it is keyed to the spider periphery for torque transmission and centering. Often the rim is shrunk onto the spider to minimize the differential radial movement between the two structures at some level above rated speed. The field poles are held by dovetails to the laminated rim.

The spider design will vary considerably depending upon the configuration of the shaft and bearing system, the type of ventilation, the machine speed, and the ratio of rotor diameter to axial length.

Large low-speed machines with the thrust bearing above the rotor usually have a continuous shaft through the rotor. In this case, the spider is either shrunk on and keyed to the shaft, or bolted to one or two flanges forged integral with the shaft. Some medium-speed machines may also have this construction.

Large low-speed machines with the thrust bearing below the rotor usually have the main shaft terminating at the underside of the spider hub. The spider hub must be designed for this attachment, which will utilize one or more of the following: fitted bolts, bolts and torque pins, radial keys, or radial dowels.

Large medium-speed machines with large axial length compared to rotor diameter often are built with the spider hub serving as a section of the total shaft system. This construction is most common where the thrust bearing and a guide bearing are below the rotor, and there is need for a second guide bearing above the rotor. The main shaft terminates at the underside of the spider hub. An upper shaft is bolted to the top of the spider hub, thus completing the shaft system between guide bearings.

High-speed generators generally require a rotor spider, which is built up of circular steel laminations, plates, or forgings. The poles are attached to the outer periphery of the spider by dovetails. The spider is shrunk on and keyed to the shaft.

5.4 Shaft and Coupling

The generator coupling is often forged integrally with the shaft. The thrust block or collar, which transmits all vertical forces from the shaft to the thrust bearing, is often forged integrally with the shaft if the thrust bearing is below the rotor. If the thrust bearing is above the rotor, a separate collar is shrunk on and keyed to the shaft.

If the turbine is of the adjustable-blade propeller (Kaplan) type, a hollow generator shaft is required so that oil pipes can be carried through the shaft from the oil head at the top of the generator to the turbine servomotor.

5.5 Thrust Bearing

The thrust bearing carries the combined weight of the rotating parts of the generator and the turbine plus the hydraulic thrust imposed on the turbine runner. Thrust bearings used are the flat-type having segmental, stationary, babbitt-lined shoes.

5.5.1 Thrust Surface

The rotating thrust surface, which transfers load to the shoes, may be any of the following:

- 1) A smooth surface on the underside of the integral thrust collar of the main shaft
- 2) A smooth surface on the underside of a one-piece thrust collar or ring which is separate from the shaft
- 3) The smooth surface may be on the underside of a circular flat plate or runner which has been precisely machined to have uniform thickness. This runner, which may be one or two pieces, is attached to the underside of the thrust collar or ring and transfers the load to the shoes.

5.5.2 Thrust-Shoe Support

The babbitt-faced thrust shoes are supported in a manner that is designed to equalize the loading between shoes and to allow each shoe to assume the proper position (slight tilt) with respect to the rotating thrust surface to establish and maintain a thin wedge-shaped oil film. The following four different forms of thrust-segment support systems are in general use:

- 1) The rigid support, or adjustable-shoe type, in which the shoes are restrained so they do not rotate, but each is free to pivot on the spherical end of a jackscREW that supports it. The jackscrews provide a means of adjusting the height of each shoe individually to obtain equal loading of all shoes. They are also used to adjust the elevation of the rotor and to plumb the shaft. In some cases, measuring devices are permanently located in each jackscREW assembly for direct measurement of the load on the shoe.