CHAPTER 13

Forces transferred to the foundations

Introduction

In water power stations the forces to be transferred to the foundations from the installed units are:

- resulting hydraulic forces from the inlet side of the turbines
- reaction and action forces from jets and jet deflectors respectively
- reaction forces from energy dissipaters
- torque forces from the generator stators
- axial forces from runners and generators via thrust bearings

For Francis and Kaplan turbines with steel scroll casing the main forces are transferred through the scroll casing to the concrete foundation. For vertical Pelton turbines the forces are correspondingly transferred through the distributor.

The transfer and magnitude of these forces are different for horizontal and vertical turbines.

13.1 Horizontal turbines

For horizontal Pelton and Francis turbines normally all the hydraulic forces from the inlet penstock are transferred to and carried by the flange at the inlet end of the penstock via a rigid connection through the inlet shut off valve.

In Pelton turbines the minor reaction forces from the jets and the action forces from the deflectors during rejections, are transferred through the housing to the concrete foundation. The resultant of the jet forces on the runner and the runner weight are transferred to the radial bearings which are bolted to the concrete foundation. The torque forces are transferred to the generator stator foundation.

For a bulb turbine the forces are transferred to the foundation in the river ground through the concrete in which they are embedded. The dominating horizontal hydraulic force is transferred via the outer cone and the main struts. The struts transfer the axial and radial hydraulic forces from the turbine. The torque from the generator is transferred through the generator foundation and partly through the turbine structure. The turbine structure is dimensioned for the total axial force with closed guide vanes.

In addition to the axial forces the outer cone and plate cylinder in bulb turbines are exposed to radial expansion. This effect requires a heavy reinforcement of the concrete in the area around the struts.

13.2 Vertical turbines

The vertical Pelton turbines installed in cavern power houses normally transfer the axial forces from the distributor through the concrete to the rock wall on the downstream side of the power house.

The maximum magnitude of this force is

$$F = \rho g H_{max} \frac{\pi D_c^2}{4} \tag{13.1}$$

where D_c is the outer diameter of the dismantling pipe (of telescopic type with seal ring) located downstream of the inlet shut off valve. The reaction forces from the jets are negligible compared with the static hydraulic forces on the distributor. This is easily stated by calculation of the maximum reaction force of each jet

$$F_j = 2\rho g \frac{\pi d_j^2}{4} \tag{13.2}$$

where d_j is the maximum jet diameter.

However, to transfer the large axial forces to the power house an extension of the inlet flange of the distributor must be welded to the inlet flange. This extension which is indicated by (E) on fig. 13.1, must be introduced to reduce the specific pressure on the concrete and avoid crushing and cracking. This purpose comprises also the necessary reinforcement bars which are laid in to avoid cracking of the concrete during pressurising of the distributor.

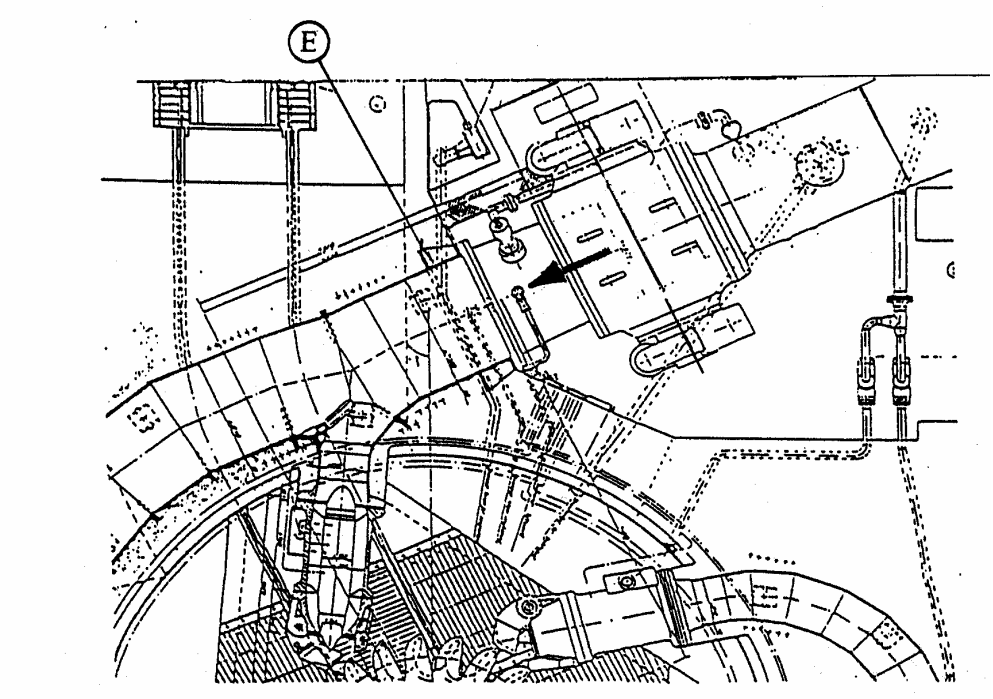

Fig. 13.1 Reinforcement collar for transfer of axial forces on a Pelton distributor.

An extension of the same type and an installation analogous to that for the Pelton turbine is applied for high head Francis turbines as well.
For high head plants the hydraulic forces carried by the tangential stresses in Pelton turbine distributors or scroll casings of Francis turbines are so large that only a negligible part of the hydraulic load is to be carried by the concrete. The reinforcement bars are laid in only to avoid cracking. Moreover, five millimetres soft material are also put in on the steel plates where the deformation is large in axial direction.

The spherical inlet shut off valve is normally free to slide horizontally on its foundation plate on the top of the concrete foundation. Vertically however, the valve is anchored to avoid vibration during closure with open needles.

For high head Francis turbines the hydraulic forces transferred to the concrete foundation are similar to the forces from a vertical Pelton turbine.

However, reinforcing bars which are located at each bifurcation in a distributor will not be used for a Francis scroll casing.

It should however, be emphasised that no welding is allowed of reinforcement bars to the high tensile strength steel plates in the stress carrying parts of high head Francis and Pelton turbines. The reason is that dangerous hardening and cracks may occur.

The vertical forces on the foundation, i.e., in the axial direction of the turbine shaft, are the weights of the turbine and the generator stator and the axial forces from the thrust bearing. In addition on Francis turbines there is a by-pass from the scroll casing through an energy dissipater. During rejections the valve in the by-pass opens according to the governor regulation. The corresponding reaction flow force is transferred vertically as well. In the rotational direction the torque of the unit transfers twisting forces to the foundations.

The twisting force and all the vertical forces which are of minor magnitude compared with the horizontal hydraulic force from the inlet conduit, are transferred through the reinforced concrete structures to the rock wall and bottom of the cavern.

The forces transferred to the power house from vertical turbines described so far, are valid only for cavern power plants with solid rock on the downstream side.

For vertical turbines in open air power houses the horizontal axial forces must be transferred to the penstock flange by a rigid connection through the inlet valve as described for the horizontal turbines.

For Kaplan turbines with scroll casing there is normally no inlet valve. The inlet of the scroll casing is then welded to the oulet of the conduit and also in this case the axial forces are transferred to the penstock.

On account of large dimensions and flexible design the vertical forces from the scroll casing will partly be transferred to the concrete foundation by utilising the weight of the generator.

Especially for Kaplan turbines with unlined concrete scroll casings a large support from the generator weight may be utilised in addition to the anchoring of the stay ring.

The trust bearing is often located in the turbine pit below the generator. In this way the weight of the rotating parts are transferred via the upper turbine cover to the stay ring.

References

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