Schematic diagram of francis turbine

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This is the first article in a 4-Part series on Hydraulic Turbines:

Part 1 – Understanding the flow through Francis turbine.Part 2 – Cavitation in turbines.Part 3 – Influence of Meshes on Hydraulic Turbine CFD.Part 4 – Grid Convergence Study for Francis Turbine- From a Meshing Software Perspective.

Hydraulic turbines have been a power extracting device from water for over two centuries. Historically in the initial phase of their application, water turbines were used widely for industrial power generation. Later, with the advent of electrical grids, they became popular as electrical power generating devices.

There are many types of hydraulic turbines; the most common ones are - Pelton turbines, Francis turbines and Kaplan turbines. Though all three types of turbines are designed to meet the objective of power extraction from water, they differ in their working mechanism and operating conditions.

This article is the first in a series of articles on Hydraulic Turbines, covering various aspects like the difference between Pelton-Francis-Kaplan turbines, the working mechanism, and flow disturbances in Francis turbines.

One of the striking differences is the mechanism by which the rotating force gets generated in the turbine. In Pelton turbines, the pure impulse force of the water jet rotates the impeller. In contrast, in Kaplan turbines, the force is purely reactive. The pressure differential created around the blades generates a lift force that drives the impeller. On the other hand, both impulse and lift force in Francis turbines contribute to power generation.

Another difference is that Pelton turbines are suitable for places with water stored at high altitude, which enables to attain high head and high velocity, while Kaplan turbines are better suited for locations with high water flow rate and low head. Francis turbine comes in between for medium head and medium flow rate applications.

Of the three, Francis turbines can work efficiently for various operating conditions. Hence, it is the most popular among the three and contributes to over 60 percent of global hydropower generation.

In the following section, we will try to understand the Francis turbine in more detail. It will cover aspects like its working mechanism and flow physics, including fascinating physical phenomena like the helical rope vortex.

The turbine consists of an outer spiral casing, followed by a set of fixed blades called stay vanes. Next comes a collection of moving blades called guide vanes, then a bunch of centrally placed blades called runner and lastly, an outgoing duct called a duct draft tube. Figure 2 shows the various parts of a Francis turbine.

The flow enters the Francis turbine through the spiral casing. Decreasing the cross-sectional area of the casing ensures that the flow enters the central part of the turbine with uniform velocity throughout the perimeter.