Acoustic scintillation Flow meter

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Introduction

Acoustic methods are widely used for measuring for measuring flow in open channels and closed conduits in various applications. In hydroelectric plants the "Transit-Time" technique is a famous method which is used in many efficiency measurement projects and its market is expected to grow more and more in the coming years. In the last decade a new acoustic technique called ASFM was introduced which offers some unique advantages for measuring intake flows in hydroelectric plants.

The special ability of ASFM , as an accurate and cost-effective means for flow measurement in short intakes of hydroelectric plants , makes it a more suitable choice for plant owners than other alternate technologies. Turbine discharge at low head plants, are extremely difficult to measure accurately, because of their short rapidly converging intakes and uneven or even unstable velocity distributions. Traditional discharge measurement devices which are applicable at these positions are current meters and transit-time acoustic flowmeters. However, they are invovled with some practical difficulties such as the introduction of instruments into the flow, intensive labor requirements and necessity to dewater the intake for installation. ASFM by overcoming these problems, offers an innovative solution which is as accurate as other measurement methods.

Over the past years, ASFM has been used in many intakes of plants with Kaplan, Bulb, Propeller or other types of turbines and now its advantages are generally accepted. The increasing competitive electricity market results in that hydroplant owners to be interested in operational improvements and more accurate measurements of plant efficiency. ASFM with its special abilities can response to these increasing demands. This paper outlines the basic concepts of ASFM, its development history,it's applications and it's instruments operating procedures.

Principles of Operation

ASFM is abbreviation of "Acoustic Scintillation Flow Meter" uses a method called acoustic scintillation drifts to measure flow velocity and is applicable only to the turbulent flows.Turbulent flow carries an amount of small eddies which cause variation in the intensity of sound waves which are traveling through fluid flow. Suppose that two ultrasonic transducers are as a transmitter and a other receiver are placed on opposite sides of a waterway and transmitter sends acoustic waves with constant intensity to the receiver. This set is called an acoustic path. Due to fluctuations in turbulent flow passing from an acoustic path, the sound received by the receiver has some random variations in the intensity which is called scintillation. As result the recorded signals by the receiver is similar that be shown in figure 1.

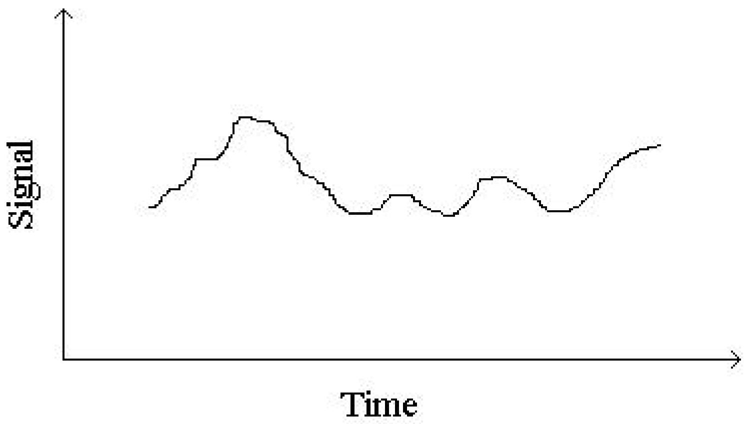

Fig. 1 : random variations in received signal

If a second acoustic path be placed sufficiently closed to the first one that the turbulence does not evolve significantly during the time required to advect it across the interval between the paths, then the pattern of scintillation at the downstream receiver will be nearly identical to that at the upstream receiver except for a time lag Δt. The lag Δt may be found by the cross-correlation (or the covariance) of the two signals over some suitable length of recorded. The lag is then is simply equal to the delay to the peak of cross-correlation curve, and the mean flow speed normal to the acoustic beams is then:

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

where Δx is the separation between the beams. A schematic representation of ASFM is shown in figure 2.

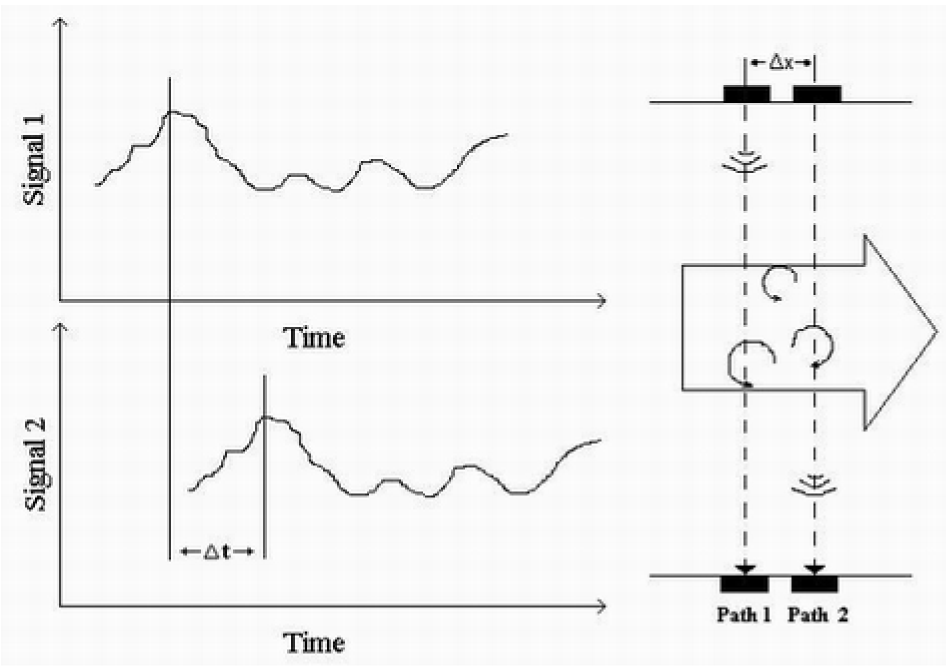

Fig. 2 : Schematic representation of ASFM

ASFM History
The scintillation drift method is a well proven technology was which first used in the late 1940's to measure solar winds and atmospheric winds using radio waves. The application of acoustic scintillation drift for measuring currents and turbulence in ocean channels began in the early 1980's.

About 25 years ago the Canadian company ASL Environmental Science initiated some efforts and studies on the acoustic scintillation technique to measure tidal currents and turbulence characteristics in open channels. This early work on acoustic scintillation flow measurement led to a patent on the basic measurement principles held by the U.S. and Canadian government. ASL has an exclusive license on these patents. Then ASL developed an acoustic scintillation flowmeter and installed it on a river with 450m wide to monitor the flow in 1989.

Only a relatively small incremental step was required to start this for hydroelectric turbine flow measurement in the early 1990's. After that the efforts has been continued in AQflow Inc. as a branch of ASL Environmental Science and led to developing ASFM as a new method for hydroelectric turbine discharge measurement. In past ten years ASFM has been installed successfully in many low head hydroelectric plants.

Application to Hydroelectric Plants
Short intakes of low-head hydroelectric plants converge quickly over very short distances, this result in an uniform flow pattern, in which the streamlines are not horizontal and the velocity vectors have a vertical components. Therefore with the use of three transmitters and three receivers at each end the average magnitude and the average inclination of the velocity can be measured at several preselected measurement levels.

In order to calculate the flow rate, the average horizontal components of the velocity at each level must be integrated over the total cross-sectional area of the intake:

$$Q = \int_0^H v(z) Cos[\theta(z)] L dz$$

where:
$v(z)$ is the magnitude of the laterally average flow at elevation z ;
$\theta(z)$ is the corresponding inclination angle;
L is the distance between the transducer faces;
dz is the element of distance vertically;
and H is the height of roof above the floor.

The integral can be evaluated numerically using an adoptive Romberg integration with interpolation in the integrand between the measured points. A velocity profile in the floor and roof boundary layers must be assumed.

ASFM measurement of the flow through a turbine requires that a location in the intakes be chosen as the measurement plane, a number of sampling paths need be established across such location as shown in figure 3.

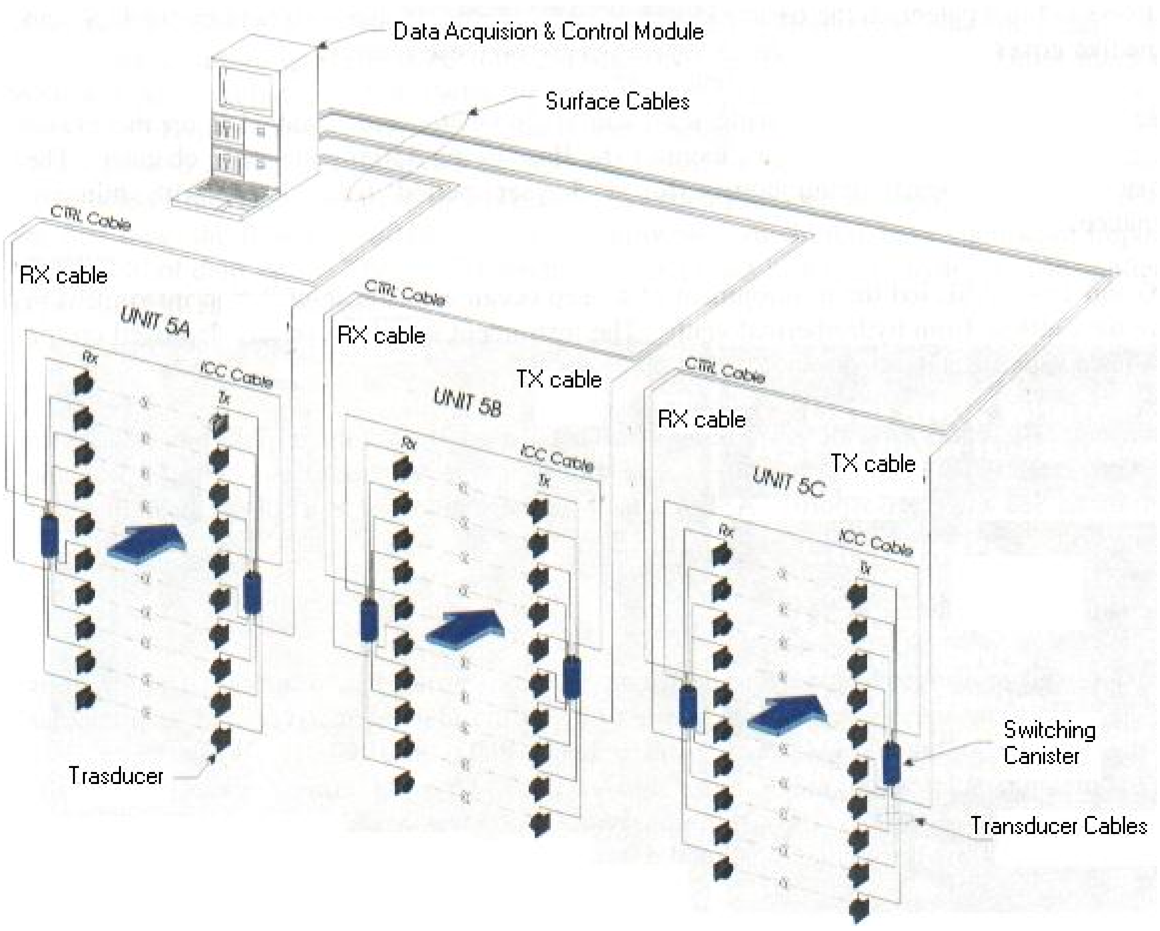

Fig. 3 : Sampling paths at several measurement levels

The transducer arrays can be either fixed to the intake walls, for a permanent installation, or attached to a frame lowered into the intake stoplog or gate slots. Using a frame in a gate slot allows the ASFM to be moved from one unit to another relatively quickly and easily, the bays and slots are all the same size. The number of the paths required to sample in the vertical is achieved either by placing arrays at every desired heights on the frame, or by using fewer arrays and moving the frame to the required elevation. Experience to-date has shown that the former arrangement requires considerably less time to conduct the measurement and is thus the prefer method.

Advantage of ASFM Relative to other Methods

The ASFM's non-intrusive nature results in a number of advantages for measuring flow through hydraulic turbines. No instruments are required in the measurement zone, thus minimizing errors due to the interference of the instrument with the flow moreover, there are no moving parts requiring maintenance and calibration. The flow measurement can be made in an intake gate slot of a plant, as it requires only that the transducers be installed at several levels along the side. This can be a great advantage for low-head plants where intake conduits are often short, and do not have any straight segments with constant cross-section for other methods to work.

The ASFM transducers can be mounted on opposite sides of a movable support frame which are lowered into the intakes stoplog or gate slots. It minimizes the required plant downtime during installation and removal, does not require intake dewatering and, in multiple unit plants, permits repeated use of the same frame without removal/reinstallation of the equipment from/to the frame. By implementing a three element transducer array, the simultaneous measurement of both the horizontal and vertical velocities is possible which is particularly important in presence of major fish screen structures upstream of the intake gates. ASFM has no intensive labor requirements and is as accurate as other traditional discharge measurement methods but it is faster, easier and cheaper to use.

Industry de-regulation, an increasing competitive electricity market and steadily rising demands on water resources make the efficient operation of hydroelectric turbines more important than ever. Absolute discharge measurement is a key part of efficiency assessments. ASFM makes those discharge measurements much easier for application such as:

- Assessing existing turbine efficiency
- Accepting new or upgraded turbines
- Improving operating efficiency
- Assessing efficiency loss due to fish screens
- Determination of optimum setting for maximizing turbine efficiency

Also ASFM can be used for other applications such as spillway discharge measurements and detection of trashrack blockages.

References

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