Development of a Low cost Fiber optic Tsunami Monitoring System

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Abstract

Due to the large scale devastation done by Tsunami, in nearly 22 different countries, in December 2004, interest in the development of tsunami warning system is increasing very rapidly in the developing countries as they have large amount of funds available for this purpose. Main purpose of the tsunami warning system is to sense the approaching Tsunami, much earlier, so that life and material may be saved. As huge investment is needed, a proposal, based upon solid base is presented for possible discussion in the conference. This paper, mainly deals with the development of sensors which can be prepared at low cost but with good accuracy. These are the sensors for the measurement of velocity of flow of water and increase in height of water level. Due to the involvement of under sea water instrumentation, it is preferred to use fiber optic sensors which can work nicely in water as no electrical signal is involved. It has multidimensional advantages over other types of sensors. It is basically dependent on the fact that tsunami speed decreases and water level increases as the shallower areas towards the sea shore are approached. Two velocity and height sensors will be installed at a distance of one km. the change in velocity and height will indicate the approaching Tsunami.

Keywords:

Tsunami, Fiber-optic sensors, Depth sensor, Flow Velocity Sensor

Introduction

A tsunami is generated due to an earth quake, volcanic eruption or under water rockslide. It is a series of waves that have time periods between consecutive crest passages typically between a 20 and 30 minutes. In any ocean wave time period never changes on being generated. The spatial period, height of the wave, and velocity of propagation change depend on the water column depth [1]. Initially, speed of Tsunami wave may be as high as 700km/hr in deep sea (4000m) and at the same time it may have a crest height of the order of 20cm only with a time period of 20minutes. It can not be detected in deep sea by observing the surface easily. However, deep sea equipment, can easily observe the generation of tsunami wave. Large numbers of tsunami warning systems have been developed but most of them are very costly and does not suit the developing countries. In this paper we have solved the Tsunami warning problem using fiber optic sensors. It will prove ideal system, with respect to cost, reliability, permanence and low running cost and simplicity. One fiber optic sensor will sense the variation in the depth of sensor and more than one velocity sensors will be fused together to sense the direction and approximate value of the velocity of the water flow [2].

Theoretical Aspects

The main purpose of this design is to decrease the cost and increase the repeatability. Optical fiber is ideal for transmitting the signals to long distances with least attenuation. For under water operation it is ideal because it is not having any electric supply and is generally made of polymers or ceramics which are quite neutral with sea water. Effect of the change in temperature will not affect the sensors because their technical characteristic does not change by first order. The proposed tsunami warning system is shown in Figure 1. It consists of a Power management system, Sensor system and Mechanical arrangement to float it and keep it at the same place, as far as possible. Here, sensors have been the main target and will be discussed in details. The basic structure of the warning system is shown in Figure 1.

Measurement of Velocity of Tsunami wave

Most important thing associated with Tsunami when it reaches the beach of unfortunate country is its speed of movement water. It is desired to sense the speed of the Tsunami much earlier than it hits the sea beach. For this purpose it is proposed to use the diaphragm based pressure sensor [3]. The proposed sensor is shown in Figure 2.One side of the diaphragm will be exposed to the moving water while other side will be completely sealed after installing a fiber optic probe as shown in Figure.1.

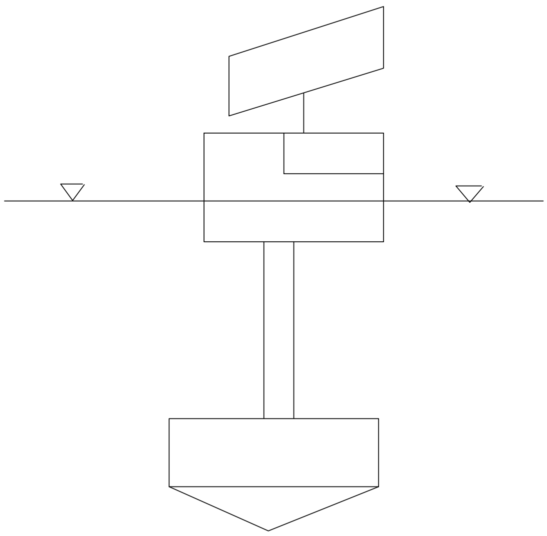

Figure 1-Tsunami monitoring system

Relationship between velocity and pressure developed on the diaphragm may be given by following expression:

Developed for the case of Pitot- Static tube developed for the measurement of velocity magnitude of liquid:

$$V = \sqrt{2(p_{stag} - p_{stat})/\rho} \quad (1)$$

Where, V=flow velocity

ρ =fluid mass density

p_{stag}=Total pressure free stream

p_{stat}=static pressure, free stream

(p_{stag} - p_{stat}) can be accurately measured with the help of diaphragm and optical fiber sensor based on intensity modulation. The complete details are shown in Figure 2.

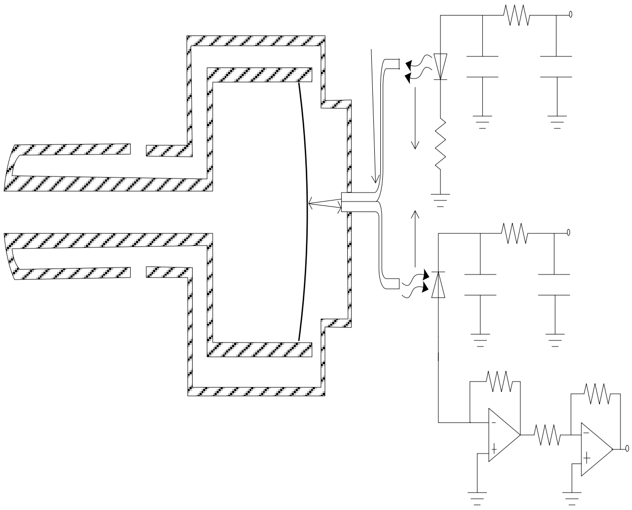

Figure 2- Fiber-Optic Flow Velocity Sensor

These velocity sensors will be provided more than to assess the velocity in different directions. By placing the fiber optic sensors with proper care, good order of accuracy may be obtained. Wire anemometer may be used for its calibration.

Measurement of depth of the sensor unit

It is also necessary to measure the depth of the sensor. For this purpose diaphragm type sensor with fiber optic sensor will work nicely [2]. In this sensor diaphragm will sense the static pressure due to water column. It is shown in Figure 3 the position of fiber optic probe with respect to diaphragm will be critical and it will decide the range and sensitivity of the measurement. The thickness and the shape of the diaphragm will also play important role. The static pressure developed due water column may be given by following expression:

$$P = \rho g h \quad (2)$$

Where, P is the pressure acting on the diaphragm

ρ is the density of water

g is the acceleration due to gravity

h is the depth of the sensor

Hence movement of the diaphragm will be the function of the depth of the sensor.

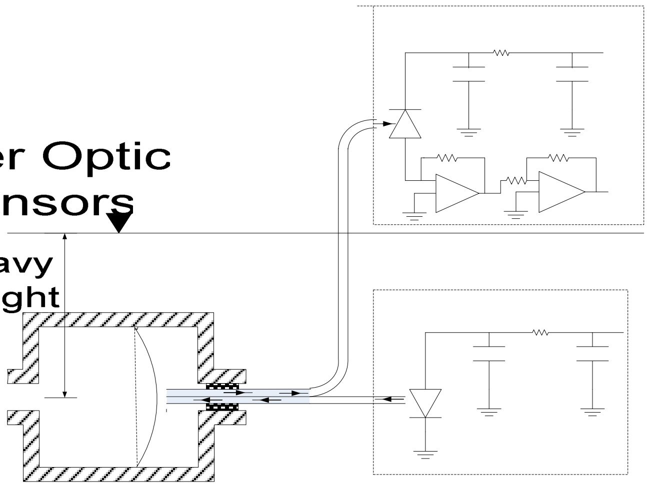

Figure 3- Fiber-Optic Depth sensor

However, results will be affected by the variation of density of water at different depths which can be corrected after taking the variation of water density from the standard tables.

Power supply to the complete Warning system

Power requirements of the whole system will be very small due to the employment of the optical fiber sensors which can be taken care off with the help of small panel of the solar cells. However solar cells may be kept in side the system and light energy may be transferred through heavy duty optical fiber cable and optical multiplexer [4].

Complete Warning system

The sensors, power unit and warning system will be installed on a floating unit which will be held at some place away from the seashore and held at one place with the help of heavy weights. The warning system will be operated by the output signals of the sensors. Depending upon the severity of Tsunami signals, warning will be conveyed by colors or Alarm. If necessary some intelligence may be introduced with the help of microcontroller based data acquisition system.

Conclusions

It is a very interesting, low cost Fiber optic Tsunami Warning System. Due to the use of optical fiber, life of sensing system will be very high because optical fiber itself has very long life(approximately hundred years).The portion of the sensor which will be under water will have no Electric power. Light signal will be changing with the variation in velocity of water flow and depth of the sensor. Other parts of the sensors can also be made out of high quality polymers so that whole unit may be free from the ill effects of saltiest sea water. As tsunami warning system has to remain active through out the year, low power consumption, low cost, reliability, stability and robust structure are the most desirable features for the installation of tsunami warning system.

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