A new Leak Detection and Activity Control System

By A. Turbin

The Omega Company has developed and implemented a multifunctional integrated system of continuous monitoring of technical and technological condition of extended facilities. Using both the distributed temperature and vibrations sensors (DTS and DVS), the system provides high-precision detection of location and nature of acoustic vibrations, spatial displacements and temperature characteristics of extended facilities such as pipelines, oil wells, railways, highways, bridges and power lines, a new function of Airports Dispatching using FOC sensors is developed. In comparison to similar systems the Omega System shows high accuracy (5 m) both of event detection on extended object and sensor displacement (20 to 30 mm on 6 m length in any direction).

BACKGROUND INFORMATION

In the first days of May near the 777 km mark of the Baltic Pipeline System-2 (a Russian oil transporting society OJSC Transneft export trunk pipeline with total length of about 1,000 km and capacity of 38 million tons running between Bryansk city and the Leningrad region) a group of suspects were detained red-handed trying to install an illegal tap by means of high-pressure hoses. Days earlier at the span “361-399 km” of the oil pipeline “Kuibyshev – Tikhoretsk” run by “Privolzhsknefteprovod” a local farmer was prevented from cutting the piping with a plow apparently trying to dig an agricultural ditch.

The dump injection into oil wells was the first practical implication of the all-Russian developed System realized by a group of scientists and energy specialists which emerged some ten years ago. The Ashaschinskoye field in Tatarstan employed by the Russian 5th biggest oil company Tatneft still uses the Omega™ equipment installed five to seven years ago.

Of course is the use of the Fiber optic cable (FOC) as the sensor not a novelty – corresponding scattering effects have been discovered decades ago, partially by Soviet scientists. Interest deserving are some abilities of the Omega™ Systems which draw a growing attention both in Russia and abroad.

The most important of them is the unprecedented accuracy of event detection on extended facility – 5 m on the 100 km span controlled usually by one logical module for third parties activity. Another advantage is the achieved combination of the on-line monitoring option with the possibility of the events’ playback and analysis.

The Omega™ Company grants a low false alarm share due to a huge influences library gathered in recent years through the LDACS implication on some 3,500 km of the Transneft pipelines laid down in different geological, climate and chemical conditions of the soil (overwhelming majority of Russian pipelines are buried). It is exactly this variety which prevents us from stressing the simplicity of System installation: laying the FOC together with the piping is much more simple preferring the so called 2 o’clock or 4 o’clock positions as for the interposition of the pipe and the FOC. In case of the installed piping the Omega™ design is a result of a compromise aimed in first line at the piping integrity sustaining. Thanks to some break-through options of the LDACS a certain deal of variability in the FOC positioning is achieved and implemented: through a three-degree algorithmic analysis of information acquired by the sensor we can a.o. compensate irregularities in the distance between the piping and the FOC through a special algorithm developed with much practical input for the latest four years.

A very special date in the Company record is the August 26th of 2010: on this day the lining of the Omega™ LDACS...
from the picket 43 177 began on the second stage of the Eastern Siberia-Pacific Ocean pipeline designed to export Russian oil to China. Another milestone in the year 2011 was the commissioning of the LDACS on the already mentioned Baltic pipeline system—last fall.

The Omega™ Company developed applications range far over the oil transportation: successful projects have been realized on Russian railways, preparation for internationally acknowledged gas pipelines trials are underway.

**LEAK DETECTION AND ACTIVITY CONTROL**

Basically the applications variety of the Omega™ products is based on the combination of two main options to be found on the markets mainly separately: of the Distributed Temperature Sensor (DTS) permitting to detect 2 m³ leaks in less than one hour and the Distributed Vibration Sensor (DVS) responsible for any physical activity along the pipeline. An extra option is the Omega™ Extended Object Strain Monitoring (DTSS): at the trials in December 2011 on a Transneft testing field the Systems registered the 20–30 mm bending deformation of a 530 cm pipeline with no direct relation to the time period of the comparative analysis.

The Omega™ DTS responsible mainly for the leak detection has been as previously said employed by the Tatneft company in heavy oil production and steam injection into the well since 2006. Serving as the distributed sensing element the FOC represents a set of virtual sensors and at the same time the transmission medium for the measurement information. The Laser diode on the logical module generates an optical impulse at a wavelength of 1,550 nm. During the propagation of light in the fiber the Raman scattering of light impulses is accompanied by the appearance of two new frequency components — the Stokes and anti-Stokes components. The main feature of the anti-Stokes component is the fact that the power of its radiation is approximately proportional to temperature. Using the OTDR (Optical Time Domain Reflectometry) technology temperature distribution along the FOC is profiled. Via comparing temperature values and its rate of change with the preset threshold it is possible to generate alarms indicating the coordinates of the anomaly.

**Distributed Temperature Sensor (DTS)**

The DTS provides following technical performance:

- Maximum coverage range without optical amplifier: 25 km
- Maximum coverage range with optical amplifier: 37.5 km
- Thermal resolution: 0.2 – 2 °C
- Type of FOC used: single mode

The DTS can be designed as one or two arms system. For the pipeline coverage of more than 25 km, a remote optic amplifier and additional fiber core is required — generally the LDACS does not require more than one fiber for each of the functions mentioned.

The processor module is an industrial type 4U frame, the unit is mounted on a rack. Uninterruptible power supply and batteries being part of the Company supply are mounted in the same rack.

The Visualization software is provided to operators to monitor the pipeline from control center, the software allows to operate the device remotely via ethernet connection. As previously stated, events information is stored in a database server for possible secondary processing. Besides the DTS can be used to measure the absolute temperature.

**FIG 1:** Transneft plans to install the Omega LDACS on 2,800 km of Russian pipeline in 2012/2013 in addition to some 3,500 km equipped with the innovative system till now. Among pipelines protected by Omega are the Purpe–Samotlor Pipeline (429 km), the Baltic Pipeline System-2 (429 km) and the East Siberia – Pacific Ocean Pipeline System (2,046 km, on the map)
In this case the DVS utilizes the Coherent Optical Time Domain Reflectometry (COTDR) to record vibrations in multiple virtual channels (up to tens of thousands at the same time) with the interference sensitivity and accuracy of the impact location of 5 m. Thousands of events can be detected simultaneously and independently – there are only the Dispatcher’s physical abilities which could lead to an unanswered event.

The DVS provides following technical performance:

- **Maximum coverage range without optical amplifier:** 25 km
- **Maximum coverage range with optical amplifier:** 50 km
- **Length of one virtual measuring channel:** 5 m
- **Sensitivity of phase change:** 0.1 – 0.2 radian
- **Range of analyzed frequencies:** 0.2 – 500 Hz
- **Pulse recurrence:** 1 kHz

Since the detection of the third parties physical activity is typical to systems similar to our one we are confident that the distance from which the LDACS detects pedestrians, cars and excavations is mere a matter of compromise and to some extend of the scientific honesty of the corresponding company. Having tuned the system to detect a walker-by from 100 m in pracis we would definitely drive the dispatcher mad through hundreds of false alarms. The Company declares the detection ranges keeping in mind this compromise between common sense and demonstration abilities – and the actual threat to the piping emerging from the corresponding activity.

DVS provides detection range as follows:

- **Activity type**
  - Pedestrian movement: Up to 1.5 m
  - Manual digging: Up to 5 m
  - Vehicle movement: Up to 7 m
  - Excavator digging: Up to 30 m
  - Heavy vehicle movement: Up to 15 m

DVS can be designed as one arm or two arms system. For the monitoring of more than 25 km, remote optic amplifier and additional fiber core is required. In this case the second fiber is used to pump optically the remote amplifier which is mounted approximately 25 km away from the location where the main system is mounted. One logical module can cover up to 100 km distance with two arms system.

**Distributed Vibration Sensor (DVS)**

In distinction to the DTS the DVS developed some three years earlier originally for some perimeter protection applications is a pipeline intrusion detection system monitoring activities in the pipeline security zone.

The DVS provides detection of third parties activity as people and vehicle moving near the piping protection area the extension of which varies depending from the national legislation. DVS can differentiate earth digging activity either by hand or mechanical excavation.

The DVS performs the following analysis:

- Detection and analysis of activities along the pipeline;
- Determination of the point of origin of the activity along the pipeline;
- Determination of running time of the activity along the pipeline.

**Author**

ALEKSEY I. TURBIN
Deputy Director General of OMEGA™ Company, Moscow, Russia
Tel. +7 916 5661599
E-mail: Turbin@Omega.mn