Investigating Avalanche Flow Characteristics in the French Alps Using CompactRIO and LabVIEW

One of the “braking mounds” being equipped.

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- Hervé BELLOT, Cemagref (ETNA)

The Challenge:
Determining the laws of avalanche flows and the effectiveness of avalanche protection barriers by gathering real-world data on flow speed and pressure.

The Solution:
Developing a rugged measurement system with NI LabVIEW software and CompactRIO hardware to accurately and reliably perform rapid data capture in extreme mountain conditions.

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Introduction

Cemagref is a research institute overseen by the French Ministries of Research and Agriculture that specializes in environmental sciences and technology. The Grenoble division of Cemagref focuses on investigating problems related to the mountainous environment. The Research Division on Torrents, Snow, and Avalanches (ETNA) set out to develop tools for preventing natural mountain risks such as avalanches, wind damage, torrential mudflows, floods, and rock falls.

Located in the Chamonix valley of the French Alps, the Taconnaz glacier is characterized by an unusual avalanche corridor of the same name. With a length of more than 7,500 m and an average slope of 46 degrees, the width of the Taconnaz corridor varies from 300 to 400 m. With the risk of avalanche trigger via fallen seracs, the corridor includes various potential start areas, the highest of which is at 4,000 m with a stopping area of around 1,100 m. The volume of the centennial avalanche is estimated at 1.8 million m^3. Officials built an avalanche barrier in the stopping area with braking mounds, deposit areas, and lateral and frontal dams.

Measuring Flow Characteristics

The ETNA research team worked in conjunction with SAPHIR, a National Instruments Alliance Partner that developed a relevant method of parametric event detection, reducing the risk of saturation due to false triggers. ETNA has collaborated with SAPHIR for more than 10 years on projects to study the elements of natural risks.

To meet the research goals, fluid mechanics specialists equipped three braking mounds of the Taconnaz avalanche barrier with pressure and velocity sensors. The team set out to determine the laws of avalanche flows and interaction with the protective barrier.

The research team aimed to measure speed (up to 60 m/s) and pressure (up to 100 rpm²) at three distinct points with synchronization at 0.1 s. The application required a measurement system that could be functional at -30 °C; was capable of sampling up to 100 kHz per channel; and offered automatic event detection, data capture, and recording of signals before and after triggering.

System Details

To build a rugged and reliable measurement system able to withstand extreme mountain conditions, researchers selected three CompactRIO chassis equipped with a controller and NI 9239 and NI 9215 analog input modules. Each CompactRIO chassis is integrated in the console with leak-proof connections. In addition, LabVIEW software controls and synchronizes the data recorders through a digital link distributed by NI 9472 modules. The seamless integration between CompactRIO and LabVIEW and the software ease of use made the products obvious choices for the application.

Extensometry Gauges for Pressure Measurements

For the force measurements, researchers used transducers based on extensometry gauges, which has the advantages of preserving low frequencies and temperature compensation. The team determined the optimal sampling frequency by determining stiffness coefficients for the sensors and sizing the bandwidth of the expected signals.

To study the cohesion of the measurement chain, the research team employed an uncertainty calculation according to the Guide to the expression of Uncertainty in Measurement (GUM) method from constructor data, which ensured that the sensor supports the measurement uncertainty. In the implementation conditions for this application, less than 1 percent of the measurement uncertainty is due to the NI 9239.

Infrared Sensors for Velocity Measurements

For the velocity measurements, the team employed a measurement principle widely used in the avalanche research community [R01: Dent et al. (1998)], which they implemented in two previous experiments at Col du Lac Blanc and Col du Lautaret. The measurement principle is based on the correlation of two signals produced by infrared reflection sensors aligned in the direction of the flow.

To implement the measurement approach on a temporary flow, researchers established a new protocol for determining metrological parameters. The uncertainty associated with the measurements considered only the bias introduced by the measuring process. The first results obtained on this device during the flow were very encouraging, but confirmation of those results will be realized with measurement of future flows.

Based on various experiments, the team adapted this measurement technique for the research site at hand. In addition, the system takes into consideration two additional constraints: the pressure an avalanche can exert on the measuring devices (sized to resist 100 tons/m²), and the maximal velocity to be measured (estimated at 60 m/s). In particular, CompactRIO is well-suited for addressing the measurement needs of the flow velocity because it offers the ability to sample at 100 kHz per channel.

Implementation

The research team buried three CompactRIO signal acquisition modules in a protective chamber close to sensors at the foot of three braking mounds on the corridor. The three modules are interconnected by an Ethernet network that is also accessible outside the device in an underground chamber approximately 300 m to away. This remotely-linked point allows researchers to consult the modules, configure them, and download acquired data.

The modules permanently record pressure and velocity signals in a circular memory allowing a data recording for 60 s. During detection of a geological event on the pressure sensors, the CompactRIO and LabVIEW system automatically saves the data record 60 s prior to and 120 s after the event. When an event is detected by one of the modules, it makes a request via the Ethernet network to the module on mound five to generate a digital signal via an NI 9472 module. This signal received by the three modules allows the team to resynchronize the specific signals recorded by each module.

Conclusion

Building the measurement system for avalanche flow using CompactRIO and LabVIEW offered specific benefits in performance and speed that make it an ideal solution. CompactRIO has a sampling rate that meets the specific needs for measuring flow, the hardware is rugged enough to guarantee reliability even in extreme mountain conditions, and the flexibility of the hardware and software platform allows for future development without a great amount of additional investment.

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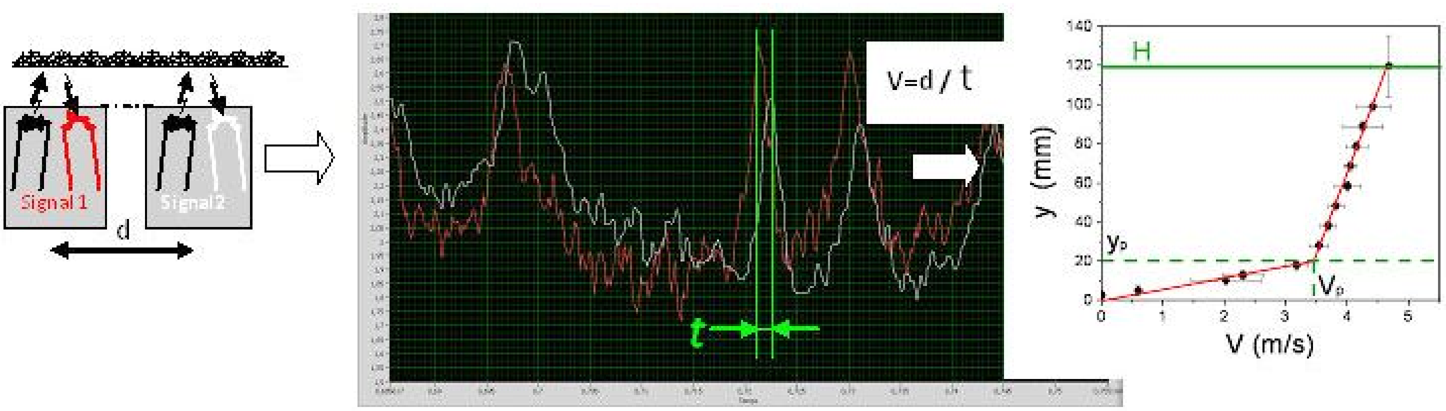
One of the “braking mounds” being equipped.

Three CompactRIO chassis are integrated into a console with leak-proof connections.



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The Taconnaz corridor, covered with the glacier bearing the same name, is more than 7,500 m long with an average slope of 46 percent.