A LabVIEW-based system for control and monitoring of a helium liquefaction plant

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A new system for control and surveillance of a helium liquefaction plant has been developed. The control system has been implemented on CompactRIO and programmed with LabVIEW. This article briefly describes the project and the helium liquefaction process.

Background

Kryolab is situated at Lund University and delivers cryogenic fluids used for cooling in research throughout the university and elsewhere in the region. Kryolab has a helium liquefaction plant that liquefies (condensates) returned helium gas so it can be reused. A new control system for the helium liquefaction plant has been developed. The control system has been implemented on CompactRIO[1] and programmed with LabVIEW[2]. The system replaces the original analogue boards and a complimentary system implemented on a SATT-control[3].

Plant overview

The returned gas is compressed and put in storage *(see Figure 1)*. The gas contains impurities, essentially air, which needs to be removed. The Purifier cools the gas until all impurities condensate or solidify and the pure helium can be transferred to a buffer tank. The purifier is then heated and purged to remove any remaining impurities.

The Liquefier is supplied with helium gas from the buffer. The liquid helium is collected in the machine tank from where it is transferred to other vessels for delivery.

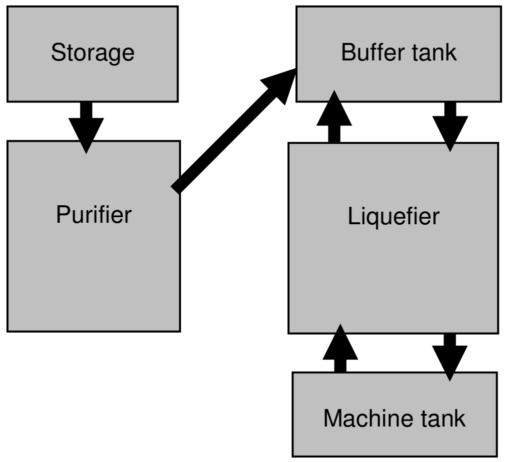

Figure 1: *Overview of the plant.*

Liquefaction process

The Helium gas is cooled in a cycle where it is alternately compressed by screw compressors and cooled during expansion through turbines. The work needed for the cooling is provided by the compressors. High pressure gas enters the Liquefier from the compressors and gas with low pressure returns *(see Figure 2)*.

On the way to the machine tank, the incoming high pressure gas is cooled in a series of heat exchangers. The part of the helium which goes through all the heat exchangers is approximately 7 K when it reaches the throttling valve (Joule-Thomson valve) leading to the machine tank. As the gas is expanded through this valve to 1.3

[1] CompactRIO is an industrial real-time controller from National Instruments. It communicates via Ethernet and has reconfigurable IO-modules.

[2] LabVIEW is a development environment for a graphical programming language with focus on dataflow from National Instruments.

[3] PLC system added for control of the plant during mid 90's.

bars it becomes a mixture of liquid and gas at 4.2 K. The liquid stays in the machine tank and the gas goes back to the low pressure return stream that passes through the heat exchangers.

The refrigeration required to keep the heat exchangers cool is provided by the turbines. After the first heat exchangers, part of the incoming gas is led to the turbines and part continues through another series of heat exchangers to the machine tank. As the gas is expanded in the turbines it cools. The side stream of gas returning from the turbines is very cold and added to the low pressure return stream. The low pressure return stream, consisting of a mixture of gas from the turbines and from the machine tank, is used to cool down the incoming gas from the high pressure side.

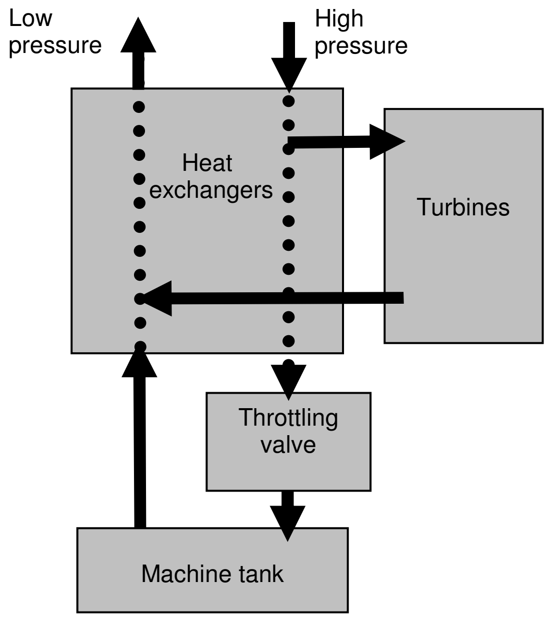

Figure 2: *Simplified view of the Liquefier.*

Method

The first part of the project was to study the behaviour of the plant. This was done with two simple VIs (LabVIEW programs) for plotting and logging and by studying manuals, drawings and data collected by the Kryolab staff. The new control system has been designed to behave as the old one, but adjustments have been made later in the project to improve the capacity.

The code has been developed iteratively and every part of the code has been tested separately before it was tested on the actual plant. An interface has been developed to allow manual input of measurement values. New functionality has been tested successively; almost every stop in the production has been used to update the code.

Control program description

The control system logic is based on state machines. The states do not specify the output signals but rather the conditions that should be met, the direction of gas flow etc. In every state several controlling actions are evaluated and performed to meet specific criteria, primarily regarding temperatures and pressures, throughout the system.

Communication

The user interface is implemented on a separate PC that communicates with cRIO over Ethernet. This communication is not in any way necessary for successful control, only to provide information to the operator. The control system is independent from the PC and the calculation of control actions has a higher priority than the communication.

User interface

The new user interface provides much more information than the old one. Measurement values, valve positions and control actions are presented on an interface similar in appearance to the original analogue one *(see Figure 3)*. It presents a simplified sketch of the plant and the piping. Some valves can also be manually controlled via this interface and it is possible to change set-points and trigger-points in the control program.

There is also a VI plotting measurement values, providing better overview of data from several cycles. This addition is particularly useful for observing tendencies in the behaviour of the plant that could indicate future problems or need for maintenance. There is also a VI for storage of measurement data in text files.

Results

The new control system has now been in use for a longer period of time and works well. There are still some smaller changes and adjustments that can be made as well as the possibility to add new functionality. This requires basic knowledge of LabVIEW and the liquefaction process.

The project has been very successful and has made it possible to run the plant under more difficult conditions than before, e.g. with higher level of impurities in the return gas, and made it easier to identify problems in the plant. The purpose of the system is to give the operator a better overview and facilitate the identification of potential problems so that proper actions can be taken. The possibility to monitor and control the plant through a computer or phone has made it possible to shut down the plant without being present and thus avoid some emergency stops.

One of the main benefits with this project has been the improved understanding and increased knowledge of how the plant works. The new control system gives the operator a better overview of how it works and enables a continuous improvement of the control system.

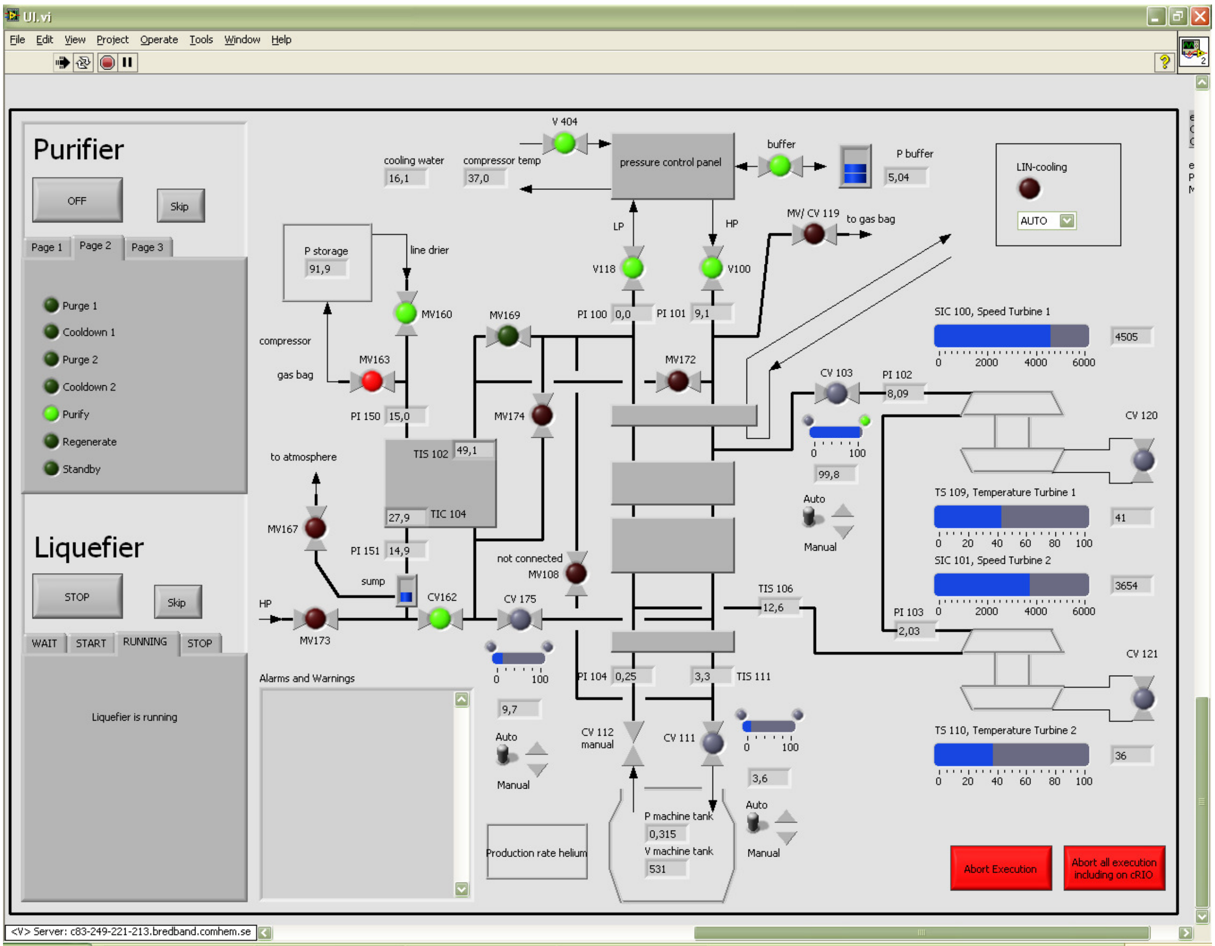

***Figure 3:** User interface based on the old control panel.*