A Slow Control System for R&D Studies on TPCs

Oliver Schäfer, University of Rostock/DESY

17th December 2008

Abstract

A slow control system for R&D studies of gaseous detectors is presented for the example of TPC-prototypes developed at DESY. Here experience gained during several experiments involving the system is reported. [1]

1 Introduction

Since about 1950 detectors in particle physics have become increasingly complex systems. Secondary measurement and control systems became necessary to ensure reliable and reproducible operation of the detectors; these are commonly known as slow control systems. In the field of gaseous detectors, the main component – the gas – is subject to changes caused by physical (temperature, pressure) and chemical (composition) conditions.[2] Operational voltages have to be controlled as well.

There are two aspects of a slow control system: firstly the conditions of the experiment can be monitored and the influence of deviations can be taken into account in a computational way over the course of data analysis (e.g. pressure corrections). Secondly all or some of the conditions stated above can be additionally controlled and kept constant. Systems controlling many parameters tend to be relatively demanding in terms of equipment and costs, but provide constant experimental conditions, an advantage especially for large experiments. On the other hand slow control systems may follow the monitoring approach. Theese just need measuring instruments and cause lower costs – however the conditions for operation of the detector can not always be steered in a way convenient for the measurements. For example changes in atmospheric conditions will influence the detector. Still this kind of monitoring system is attractive especially for

[1] cf. [6]

[2] see extensive description in [5] and [3] and more recent studies in [7]

R&D experiments, where partly just these influences are studied. The latter was also chosen for slow control of the various R&D time projection chambers (TPCs) made by the FLC group at DESY Hamburg as a compromise between the desire of gaining a better understanding of the TPC data and economy on the other side.

A TPC comprises of a usually cylindrical gas volume with two electrodes on either end. Due to homogeneous electric and magnetic fields applied along the chamber-axis ionization products drift straight to the ends of the TPC. As the anode is divided into several pads, the projection of an ionization track onto the $r,\,\varphi$-plane can be easily obtained. The z-coordinates are calculated from measurements of the drift time, thus dependant on the drift velocity. For quantitative measurements it is therefore essential to have control over pressure, drift field, and water content (gas composition), which mainly influence the drift velocity.

The primary electrons from the ionization as such would be hard to detect. In order to get a stronger signal, gas amplification methods have to be applied (wires[3], GEMs[4], MICROMEGAs[5]). Also the amplification process depends on pressure, temperature, voltages, water- and oxygen content, as do ionization and drift of the ionization products.

2 Slow Control Hardware Components

At DESY a number of TPCs are in use for different purposes, such as studies of resolution, double track resolution, drift velocity, GEM amplification, and readout electronics. The chambers are run mainly with argon based mixtures, like so called TDR-gas[6] ($93\,\%$ Ar, $5\,\%$ CH_4, $2\,\%$ CO_2) and P5-gas ($95\,\%$ Ar, $5\,\%$ CH_4), delivered in bottles, premixed from DESY's central gas group. Impurities of these gases are below $35\,ppm_V$. The dimensions and volumes of the chambers can be taken from table 1.

2.1 Measuring and controlling Hardware

All instruments are connected in series either before or after the TPC, as the used flow rates are sufficiently low ($0\ldots60\,\ell/\mathrm{h}$) to supply the chamber through the instruments.

[3] cf. [5]
[4] first described in [4]
[5] first described in [2]
[6] suggested in [1], p. 35 f.

Chamber	Volume in ℓ	Material
Large-TPC	119	Rohacell®-Kapton®compound
Medi-TPC	32.7	Kapton®-Nomex®-carbon fibre compound
Mini-TPC	6.8	aluminium
UNIMOCS	7.0	anodized aluminium
LP-TPC	210	Kapton®-Nomex®-glas fibre-compound

Table 1: Chambers used at DESY Hamburg

Flow Controller. As the first device, flow control is implemented via a two stage electronic flow controlling system. It consists of the actual controller, providing a flow meter and a control valve, and secondly a four-channel-readout unit, where flow, mode of operation, operation voltage and other I/O-tasks are handled.

Pressure. Coming back from the chamber, the gas passes a safety valve to protect the chamber and both absolute and differential pressure are measured with electronic sensors.

Oxygen Content. Next, the gas enters the measuring cell of an oxygen content meter. Its working principle is similar to a fuel cell consuming oxygen, with the difference of only one reactant being gaseous. It generates a voltage proportional to the oxygen content, which is amplified and recalculated to the oxygen content.

Water Content. After this the water content of the gas is measured with a dew point measuring instrument. This uses the phenomenon that the temperature of a gas, at which dew or frost starts to form, depends on the water content of the gas. The device employs a mirror being cooled and regulated to this dew or frost point. The appearance of dew or frost is measured via the intensity of the reflection of a light source on the mirror. The cooling of the mirror is done with a peltier element; the heat is removed by a mixed air and water cooling. For the water cooling circuit a commonly available system for the cooling of personal computers was adapted.

2.2 Mechanical Setup

As mentioned before, the devices are arranged in the gas circuit in two branches: one, to be installed before the TPC, is responsible for flow control and optional gas purification (water- and oxygen filters). The second branch, intended for installation after the TPC, analyzes the gas in terms of pressure, water- and oxygen content.

In order to provide a modular setup of the devices, they where built into a 19-inch rack. Installed in such a way, the instruments can be relatively easily transported to the various measuring sites at DESY. The only exception

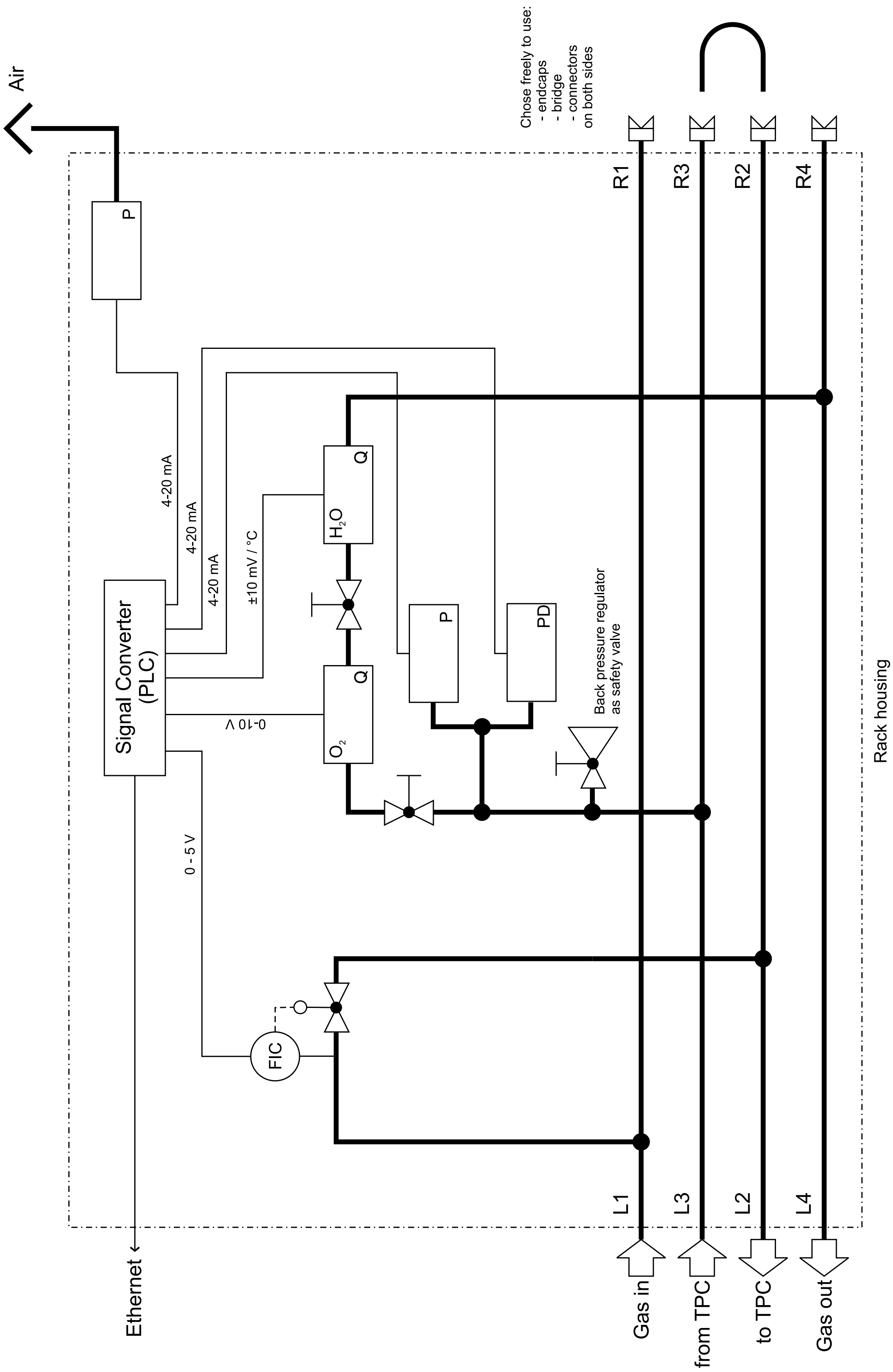

Figure 1: Flowchart of the Slow Control System Rack

is the two temperature sensors, which may be installed close to the inlet and outlet of the TPC to obtain an average value of the temperature inside the chamber.

As most of the instruments also needed connections to the gas stream, four connections where foreseen on the rack: one for fresh gas, one to supply the TPC, another for the return line from the TPC and a last one for the exhaust line. These connections where duplicated on the other side of the rack to provide a certain flexibility in the setup. Unused connections can be closed by end caps.

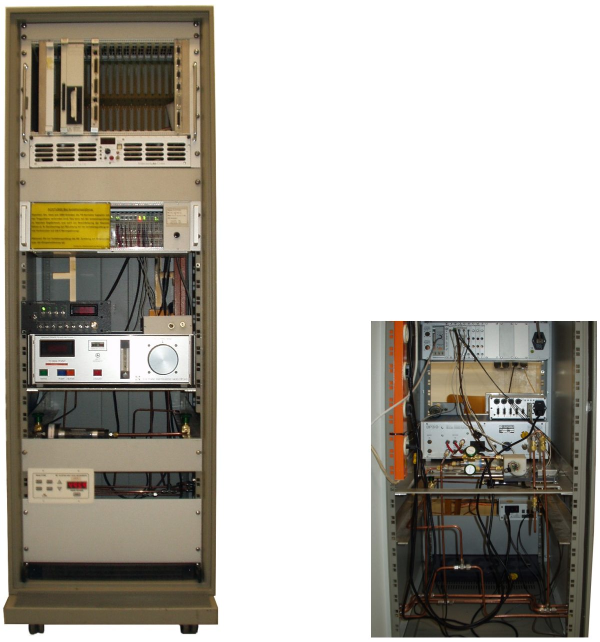

Figure 2: Slow Control Rack front and rear view. From bottom up: oxymeter, dew point instrument, flow controller, signal converter.

2.3 Communication System

Most of the devices stated above deliver a monitoring signal at the output – usually a proportional voltage, current or digital signal. All these are collected in a modular signal converting system which measures the signals (12 Bit precision) and processes them into a signal bus data stream (in our case Ethernet) that can be read out and stored via a remote PC. These systems are widely available for a large variety of input and output signals as well as different bus formats known from the automation industry. In comparison with self made or VME-based solutions they are more flexible, less expensive, and very compact.

3 Slow Control Software

The software is the second important part of the slow control system. It has the task to process, display, and store the data – eventually to evaluate and react to it. It is the interface between machine and user and should therefore be ergonomic, efficient and offer interfaces to different operational systems.

In a first, currently used version, the three basic needs are already met. It was created under MS Windows to make use of the program libraries the manufacturer of the signal converting system provides. Though working satisfactorily for the moment, the program is rather inefficient due to the fact that all the tasks (readout, processing, displaying, storing) are handled sequentially. The data is written into a file every minute, which is copied onto a web page via a set of scripts to make it available for the group and provide a certain organisation of the data.

To meet the remaining needs in addition a second version, featuring a major redesign, will be developed. It could be based on a database listing the different devices, their connection to the software, the display settings and an error-, warning-, hint- message catalog. The different program tasks will be processed more or less independently of each other in several subprocesses. Furthermore the program will work as a server for display clients using other operational systems. A more sophisticated way of alerting users, e. g. if a gas bottle is about to run empty, has also been thought of.

4 Running experiences

Since its completion in a first stage in summer 2005, the slow control system was already very helpful for understanding the operation and details of the prototype chambers. A dedicated study of the dependence of drift velocity and water content by means of ionization with two laser beams was done and is intended to be reported in another LC-Note.

From the operating point of view the modular construction proved to be useful, but also to a certain degree incomplete, as the extraction of devices from the gas line (e. g. for maintenance or calibration) is slightly difficult. The two branch layout of the overall system was found to be helpful for the measuring programmes done so far, as the analysing branch could be used for gas either entering or leaving the TPC with only little effort for reconnecting. Also the data readout structure worked satisfactorily, however it is clear that the relatively closed design, bound to a specific computer, being used at the moment, will cause problems in future applications in a multiuser context. Thus the stated redesign of the software is a crucial step to be taken for a slow control system for the future LP-TPC infrastructure. Other slow controls like those for high voltage or magnetic field were not included in the main slow control system. This did not disturb the operation much, since they could be operated from the same computers being used also for the measurements.

Concerning the measured quantities the oxygen content proved to be a very sensitive and fast reacting indicator for leaks as well as for the flushing state of the system. The water content reacts much slower due to the property of water to attach to the walls of the tubing and chamber. If sufficient leak tightness was provided, the optional water/oxygen filter showed no necessary improvement of the gas quality, being already very good by itself, and was thus usually omitted. If however non removable leaks were present in the system, it served well in maintaining a sufficient gas quality in terms of oxygen and water for a limited period of time. However nitrogen can not be included into this statement, since it was neither measured nor filtered. As an example for offline data correction pressure corrections were already taken into account for the drift velocity study mentioned above. The flow controller was successfully employed as a key element in the water enrichment system used for that study.

Often it is desirable to get a direct indication of changes in the gas gain. For this a so called gas gain monitor may be implemented. This is in principle a small, continuously flushed proportional counter which monitors the spectrum of an ^{55}Fe source. Changes of the gas gain will be directly visible as changes in the spectrum.

As the described gas system is operated as a reservoir based system open to the air it obviously has the feature of the used gas being spent at a certain rate. For the chambers in use, so far this has not been a problem, provided the required gas bottle changes were performed cleanly and in time. However, coinciding vacation times, weekends, careless bottle changes causing leaks, and a missing online control of the gas bottles caused down times of the system. Thus careful shift- and measurement planning is essential for a good performance of such a gas system. Also for the LP-TPC such a mode of operation is still feasible, considering that bundling of bottles is a practical possibility to increase the available gas supply.

Conclusion

A slow control system for prototype TPCs was built. Especially for the R&D phase a modular concept for the system (hard- and software) proved to be suitable in terms of flexibility of the setup, ease of maintenance, cost and operability. Experience from past measuring periods was reported.

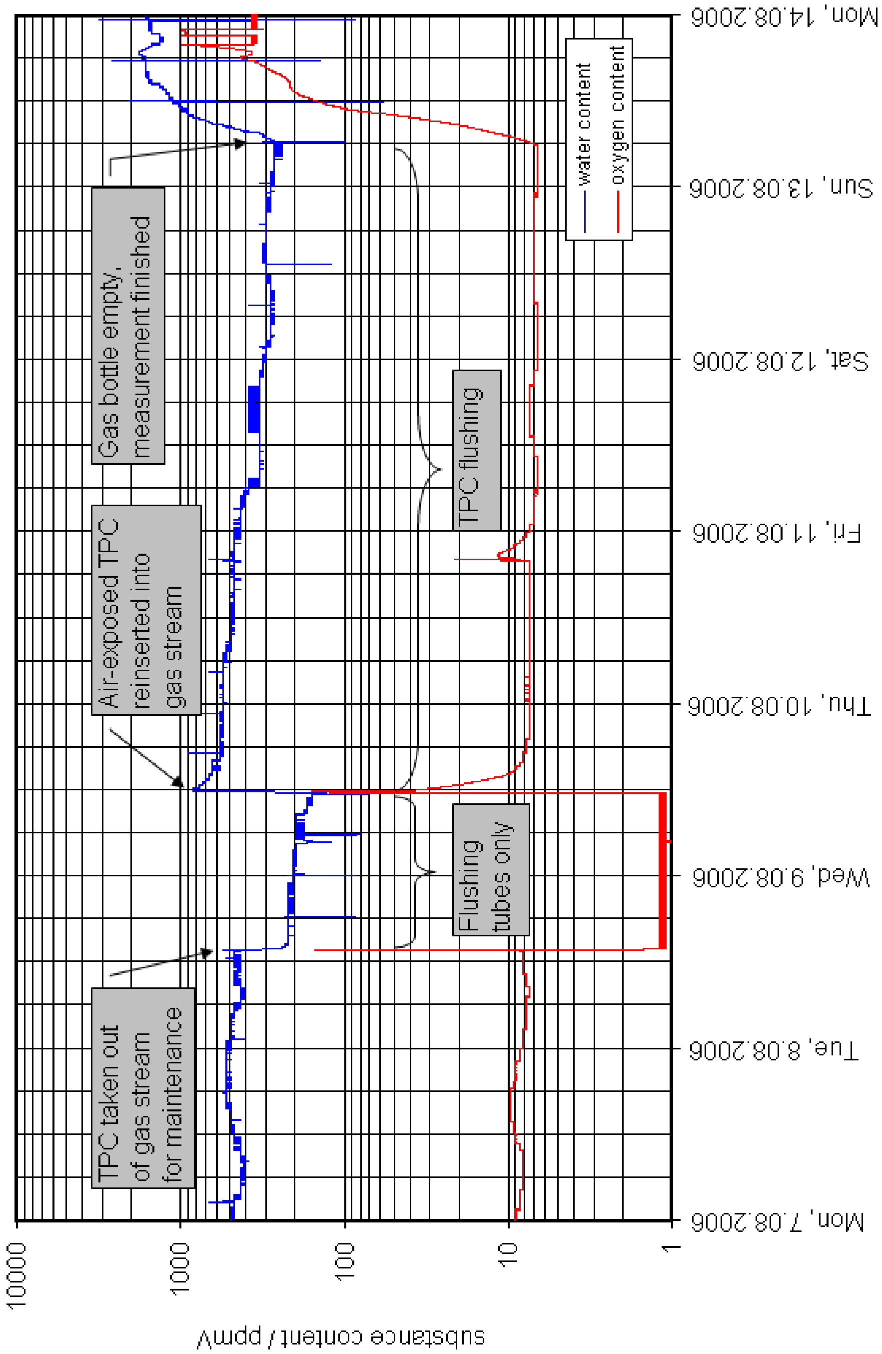

Figure 3: Snapshot from the water and oxygen content data between August, 7th and 14th 2006.

References

[1] BEHNKE, (ed.). ; BERTOLUCCI, (ed.). ; HEUER, (ed.). ; SETTLES, (ed.).: TESLA: The superconducting electron positron linear collider with an integrated X-ray laser laboratory. Technical design report. Pt. 4: A detector for TESLA. (2001). – DESY-01-011

[2] GIOMATARIS, Y. ; REBOURGEARD, P. ; ROBERT, J. P. ; CHARPAK, Georges: MICROMEGAS: A high-granularity position-sensitive gaseous detector for high particle-flux environments. In: *Nucl. Instrum. Meth.* A376 (1996), S. 29–35

[3] KORFF, Serge A.: *Electron and Nuclear Counters : Theory and Use*. 3. Aufl. New York : D. van Nostrand Company, Inc., 1947

[4] SAULI, F.: GEM: A new concept for electron amplification in gas detectors. In: *Nucl. Instrum. Meth.* A386 (1997), S. 531–534

[5] SAULI, Fabio: Principles of Operation of Multiwire Proportional and Drift Chambers. In: FERBEL, Thomas (Hrsg.): *Experimental Techniques in High-Energy Nuclear and Particle Physics*. 2nd Edition. Singapur : World Scientific, 1991

[6] SCHÄFER, Oliver: *Ein Monitorsystem für gasbasierte Detektoren am International Linear Collider (ILC)*, Rostock, Universität, Fachbereich Physik, Diplomarbeit, 2005. – http://adweb.desy.de/~oschfer

[7] SHARMA, Archana: Properties of some gas mixtures used in tracking detectors. (1998). – SLAC-J-ICFA-16-3