Advant OCS controls cryogenic installations of CERN's particle accelerator

CERN's laboratory for particle physics near Geneva, Switzerland, is among the most innovative R&D centers in the world. This approach to research is also reflected in the way it works with its control system suppliers. ABB's Advant Open Control System (OCS), which makes use of object-oriented programming, was chosen to perform one of the most complex automation tasks ever specified: processing 10,000 signals in order to keep the temperature of the world's largest particle accelerating system close to absolute zero.

The Large Electron-Positron (LEP) Collider at CERN's laboratory for particle physics near Geneva generates an enormous amount of energy in an extremely small space (see box on this page). By the summer of 1999, the collision energy had been raised to almost 200 giga electron volts (GeV). Energy levels of this kind are needed to test the standard model of high-energy physics. As the particles are accelerated by superconducting cavity resonators, very low temperatures play an important role in the experiments. In all, four 12-kW helium liquefiers supply liquid helium at a temperature of minus 269 °C to the 72 LEP accelerator modules and their 288 resonators. ABB's process control system, Advant OCS (see box far right), has been installed to control the four liquefiers. Advant OCS is fully compatible with other proven systems, such as ABB Master, thereby preserving customer investment in installed equipment.

Process control system retrofit

In 1986 CERN selected the integrated process control system ABB Master for the control and supervision of the complex cryogenic installations [1]. This system has been performing the I&C tasks as well as all the logic operations.

Hans-Karl Kuhn
CERN, Centre Européen pour la Recherche Nucléaire

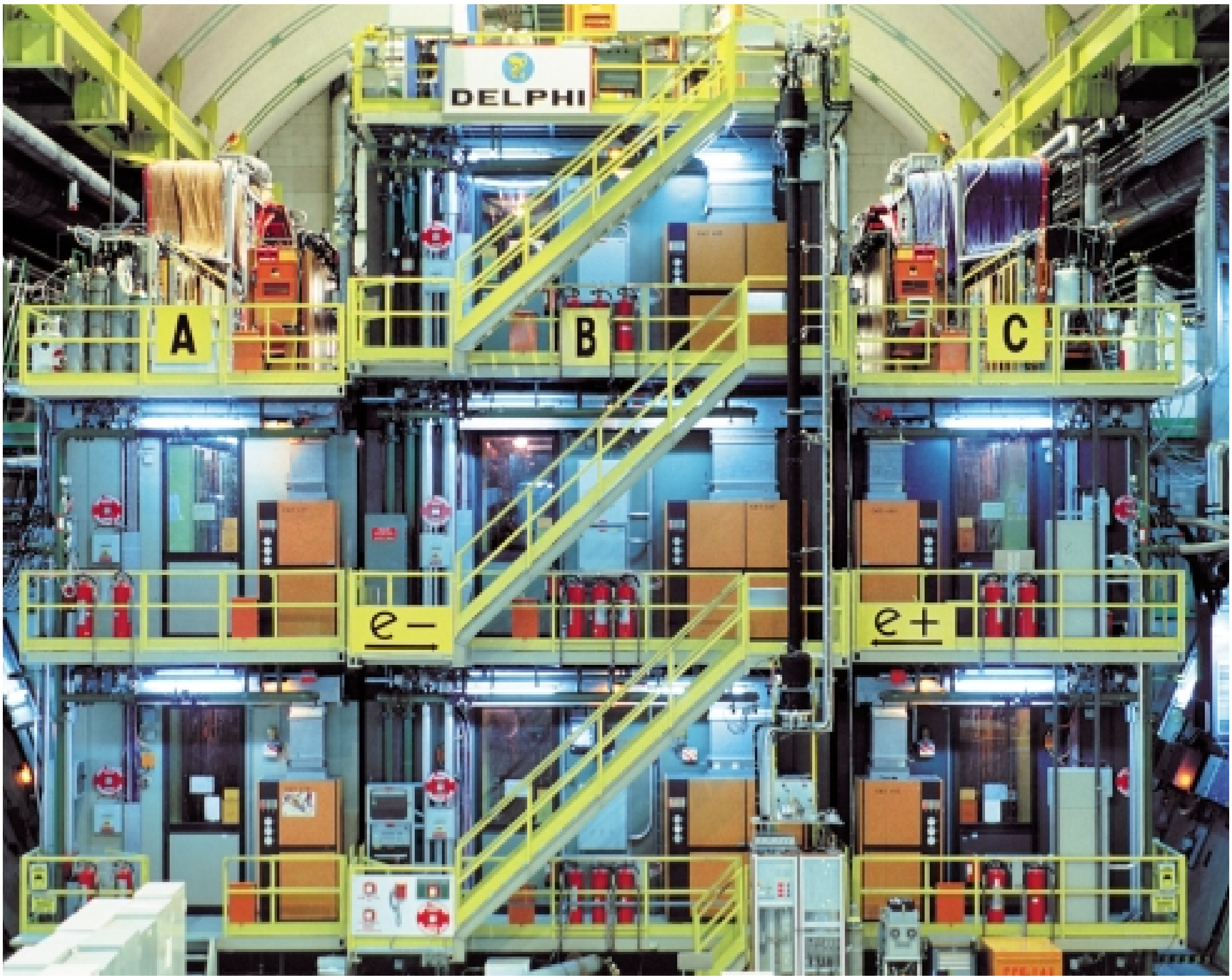
Marco Pellin
ABB Power Automation

CERN's LEP Collider

The Large Electron-Positron (LEP) Collider runs in a roughly circular subterranean ring, 27 km long, that straddles the border between France and Switzerland near Geneva [2]. The tunnel in which the particle accelerator is installed has a diameter of 3.8 m and lies at depths ranging from 50 to 170 m. Installed along the tunnel are 3,300 dipoles, which hold the electrically charged particles on their course, 1,300 focusing magnets and 600 correcting magnets. Spaced around the ring are four caverns, 70 m long and 20 m wide and high. These house the experimental areas in which the four detectors OPAL, L3, ALEPH (Apparatus for LEP Physics) and DELPHI (Detector with Lepton, Photon and Hadron Identification) are located 1, 2.

In the LEP, two counter-rotating beams, one of electrons and one of positrons, are accelerated to almost the speed of light. These LEP beams, which are injected by a Super Proton Synchrotron (SPS), consist of precisely synchronized pulses in the mA range. In the experimental areas the beams are focused and made to collide with an energy of, at present, typically 192 GeV. As a result of the collision new particles are created, in particular W and Z bosons, both of which have extremely short lifetimes. Their properties and behaviour are observed in the detectors and investigated with the help of computer analyses. Scientists expect the LEP Collider to provide many new insights into the fundamental laws of nature.

The installed power rating of the LEP collider is 75 MW, that of a 12-kW cryogenic installation for the superconducting resonators approximately 2.5 MW, the majority of which is for the helium gas compressors.



Front of the DELPHI particle detector, one of four detectors at CERN's laboratory for particle physics near Geneva. An ABB Advant Open Control System processes 10,000 signals to keep the temperature of parts of the world's largest particle accelerator close to absolute zero. **1**

In recent years the particle energy in the LEP has been increased from 90 to 192 GeV and the range of experiments widened, with the result that the MasterPiece stations, especially those used to control the compressors, have been operating close to their limits.

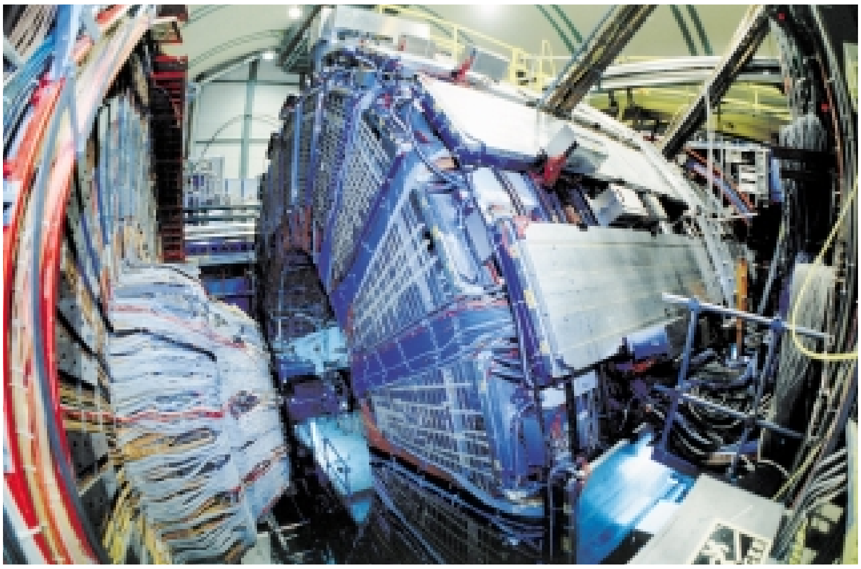
As a result of the more demanding conditions ABB and CERN have upgraded the process control system over the past few years through the addition of 34 Advant Controller nodes (10 400-series Advant Controllers and 24 200-series MasterPiece stations), two Advant IMS stations (for linking the process control system to CERN's Oracle database system), five Advant operator stations, and ten MasterView stations.

Advant OCS with open system architecture

With its Advant® Open Control System (OCS), ABB offers a standard, state-of-the-art platform with open system architecture for the automation of industrial processes. The system is characterized throughout by an object-oriented and distributed structure, high-performance operator stations, very high availability and ease of maintenance. All process and operator stations are linked by a system bus. The process control stations communicate with the I/O units by means of field buses. Every stage in the industrial process can be controlled and monitored from each of the process operator stations.

Nine local networks

The four helium liquefiers are not centralized as they have to follow the geometry



Partially opened DELPHI particle detector. On the right is the main section with müon calorimeters, on the left the end-plug with some of the cabling for the 1 million data points. **2**

of the LEP Collider. This arrangement also dictates the configuration of the controller nodes.

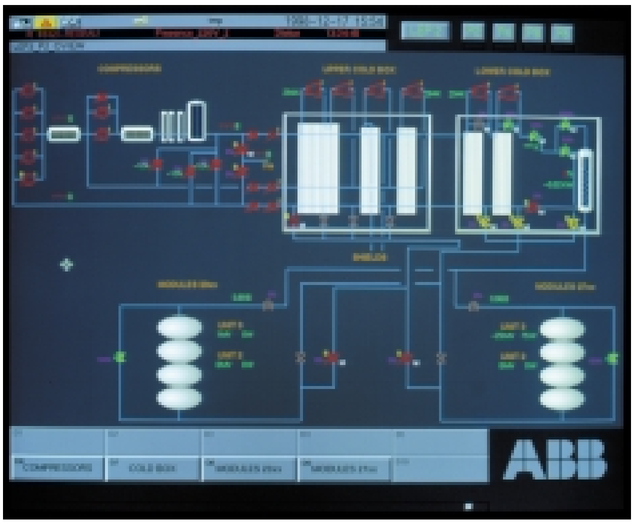
Working closely with CERN, ABB constructed nine local networks, each of which can be controlled independently of the others. The four largest and one smaller local network are also united in a central control room with a wide array of displays **3**, **4**, **5**, **6**. Each of the four large installations generates about 2,400 to 2,900 I/O signals, which have to be monitored by the ABB system, and records data on 600 trend curves. Although approximately 40 curves would be sufficient to describe normal operation of the installations, a larger amount of data is required due to the prototype nature of the equipment and the need to optimize its operation.

Flexibility is required

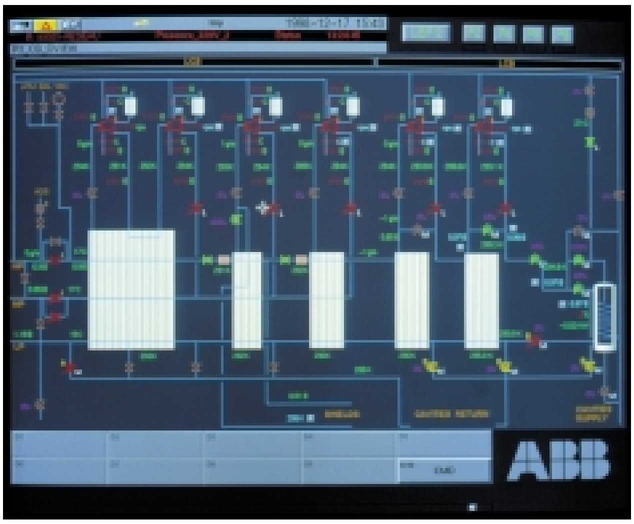
These technical details underline both the extent and the complexity of the control duties that the ABB system has to perform, the main task being to control the cooling of the cavity resonators – a process which can last 24 hours. To avoid the risk of thermal stress in the components, the temperature difference over critical parts of an installation is never allowed to exceed 50 °C. Although the thermal inertia of the cooling system is high and the control processes are usually run for long periods of time the control system must be able to respond immediately to a sudden, unexpected malfunction, such as quenching (ie, a loss of superconductivity). In such an event, the cooling circuits have to be interrupted quickly to avoid an excessive build-up of pressure.

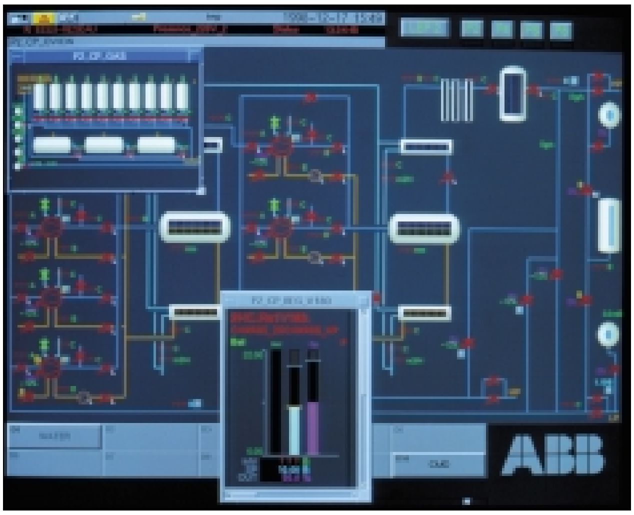
The response times for the switching

Overview of the cryogenics at LEP site 2. At top left is the compressor section, top right the upper (300 to 20 K) and lower (20 to 4 K) cold box, and below the load, consisting of the superconducting accelerating cavities. **3**

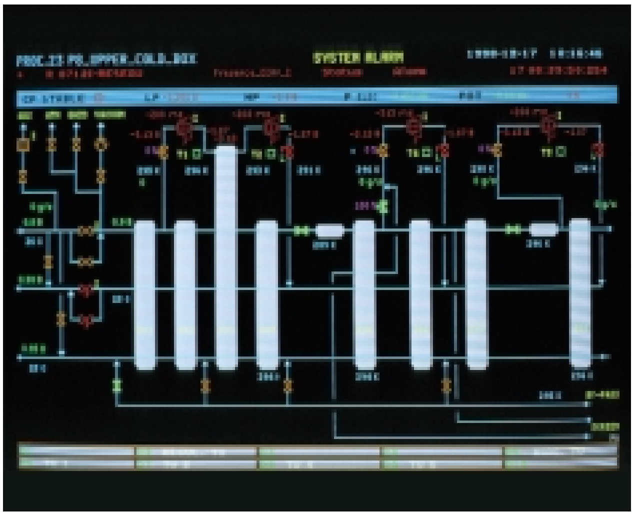


Cryogenic installation (upper and lower cold box). The helium is liquefied from 20 °C at 20 atm to 4.2 K by means of expansion turbines. **4**





Compressor stage of the helium liquefier at LEP site 2. Five parallel compressors belonging to the low-pressure section are shown on the left. The inset shows tanks holding helium gas in reserve at normal temperature. **5**



Upper cold box, in which turbines expand the helium, thereby cooling it from 300 K to 20 K. **6**

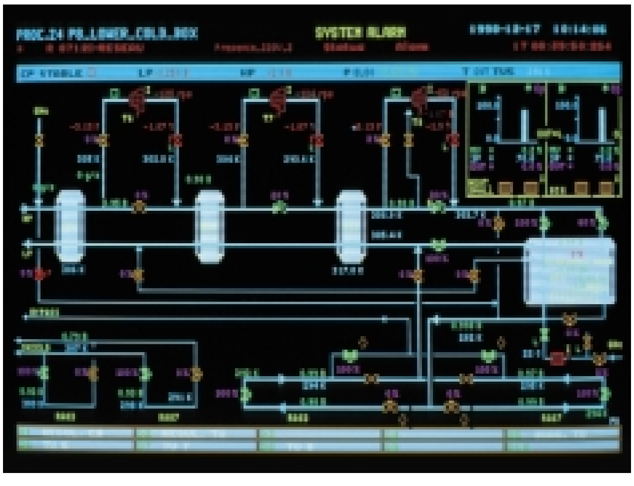
operations in the cooling circuits are measured in minutes or seconds, whereas the radio frequency of the particle accelerator has to be switched off within just milliseconds. Less than 2 kW of energy are needed to cool the lines and compensate for the heat losses; 10 kW is necessary to dissipate the heat in the resonators (ie, the heat caused by the radio frequency energy and the particle beam).

The quality of the helium also has to be routinely checked. Contamination has to be kept to an absolute minimum – no more than a few non-helium atoms per million helium atoms are allowed. The process control system therefore controls the purification of the helium, which has the lowest boiling point of any gas. This function is important since the contamination could crystallize and be deposited on the valves and turbine blades, in which case the turbines, which have gas bearings, would be destroyed.

As already mentioned, the overall process control system is so complex that several of the original MasterPiece 200

Lower cold box – the helium is cooled from 20 to 4.2 K and liquefied. Valves control the turbine pressure. From here the liquid helium flows (under the effect of the pressure difference) to the resonator cavities. **7**

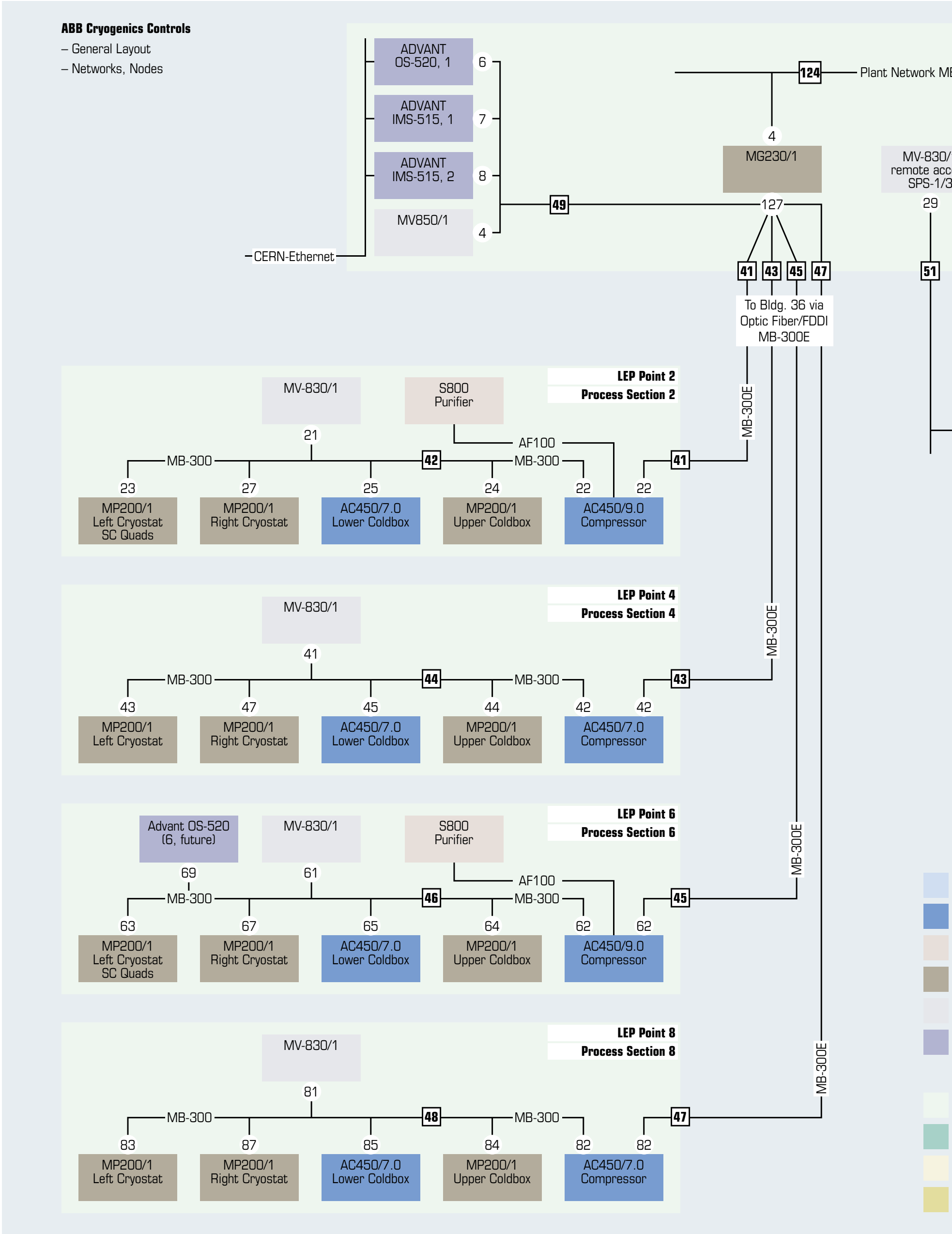
Overview of the lower cold box. An Advant Controller 450 monitors the liquefaction of the helium gas. Three heat-exchangers are shown on the left. The object on the right is the liquefier. **8**



stations [1], for example those that control the compressors, were being run at their limit. In the meantime ABB has developed the Advant Controller 450 with four times the capability of the earlier controllers and which can be nominally expanded for 5,400 analogue and digital I/Os. This new system now replaces the MasterPiece 200 stations at critical nodes in the cooling system. With Advant OCS, the cooling system of the overall plant can be controlled from a central control room, the local control rooms only being used for maintenance work or in the event of failure of the link to the central control room.

Object-oriented software

The contract awarded to ABB was also the first for a complete process control project ever to have been awarded by CERN to a single industrial concern. Since the process control technology was intended for six similar installations originating from two different suppliers (in each case, two 12-kW cryogenic installations as well as one 6-kW cryogenic plant, primarily for test-rig work **7**, **8**), CERN and ABB decided in favour of object-oriented software. Close collaboration soon produced the hierarchical structures for the software components. At the lowest level, software elements control the least complex objects, such as valves, heating elements and pumps. At the next higher level are the objects formed by joining together the objects at the lowest level. Also here are the first horizontal interlock functions, eg representing a turbine by the three objects 'gas bearing', 'input valve' and 'brake valve'. Several of these objects can be joined together to form other installation parts, such as a compressor stage. Subfunctions, such as 'resonator cooling', are initiated at this level by the appropriate commands. Coordination of the sub-

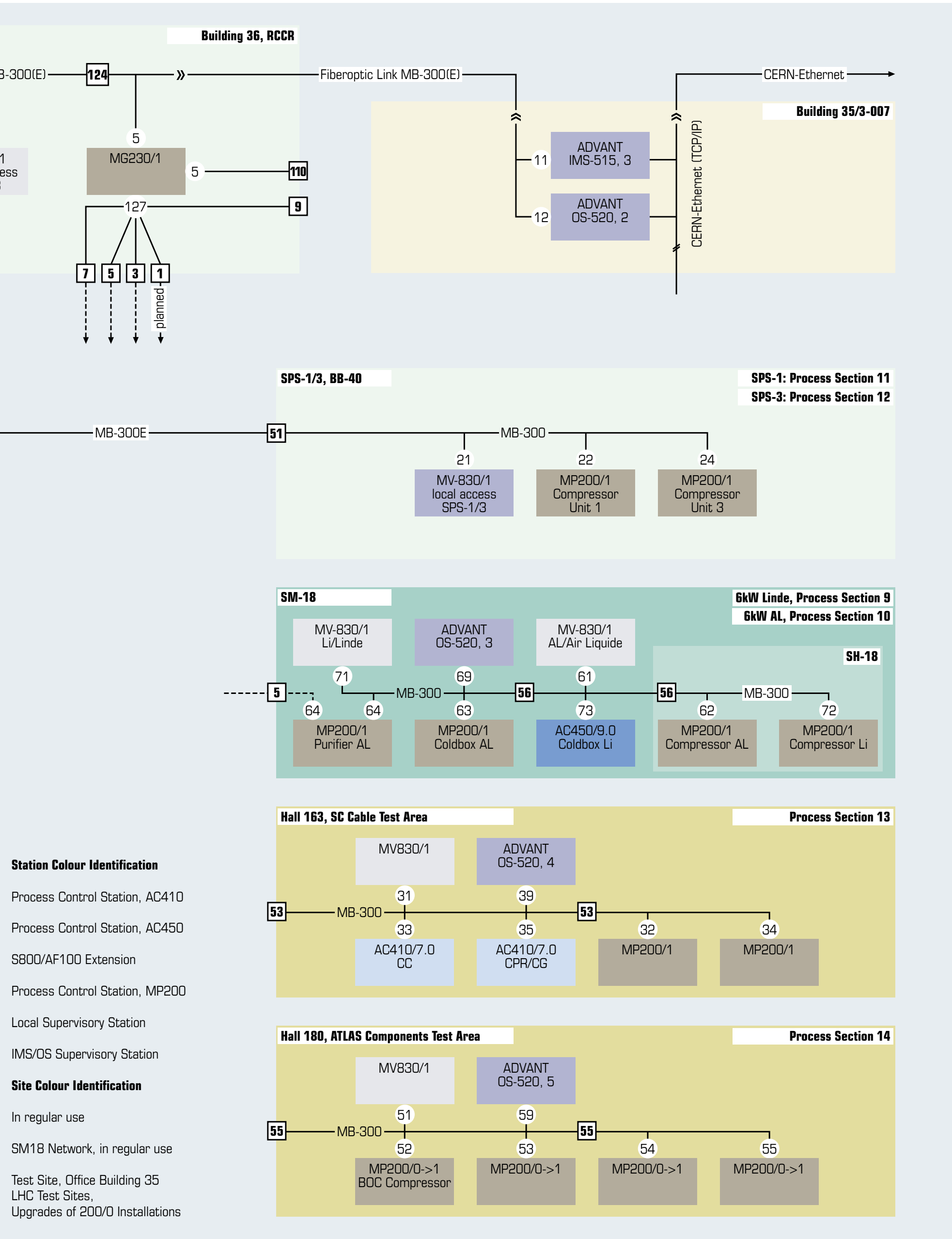


Configuration of the Advant Open Control System installed in CERN's laboratory for particle
of the LEP particle accelerator.

system interaction **9** takes place at the highest level, eg with commands such as 'begin cooling'.

The benefits of system compatibility

ABB's policy of ensuring system compatibility has continued to pay dividends during the further development of its process control systems, as evidenced by the Advant controllers: the function-block-oriented graphic programming with the programming language AMPL, which had already been in use for some time, allows 98 % of the user-programs to be transferred unchanged to the advanced AC400 controller series. Another advan-



physics, where it controls and monitors the cryogenic installations **9**

tage was the object-oriented software that ABB had introduced six years earlier and which allows applications to be programmed today for about a third of the cost then.

The installation by CERN and ABB of what was virtually a turnkey process control system went smoothly and can be considered a great success. In the meantime ABB can access CERN's local Masternet directly, which makes further development of the software and fault analysis easier. Ongoing system optimization is ensured by holding conferences which are attended by members of the research center in Geneva and ABB personnel.

At the suggestion of CERN engineers, ABB is currently testing the process control and drive systems in connection with the latest Profibus developments. The transfer of know-how between ABB and CERN testifies to the success of the collaboration and is one of the factors that speak for continuing the cooperation beyond the existing contracts and after tendering for the Large Hadron Collider (LHC), which will generate a particle energy of 7 TeV (1 TeV = 1,000 GeV) per beam, compared with 192 GeV for the LEP.

Reference

[1] **S. Fors:** ABB Master controls cryogenic installations for the world's largest particle accelerator. ABB Review 8/9-90, 3–10.

[2] CERN Annual Report 1998, vol 1.

Authors

Hans-Karl Kuhn
CERN, Centre Européen pour la Recherche Nucléaire
CH-1211 Geneva
Switzerland
Telefax: +41 22 767 95 80
E-mail:
hans-karl.kuhn@cern.ch

Marco Pellin
ABB Power Automation AG
CH-5401 Baden
Switzerland
Telefax: +41 56 486 73 73
E-mail:
marco.pellin@ch.abb.com