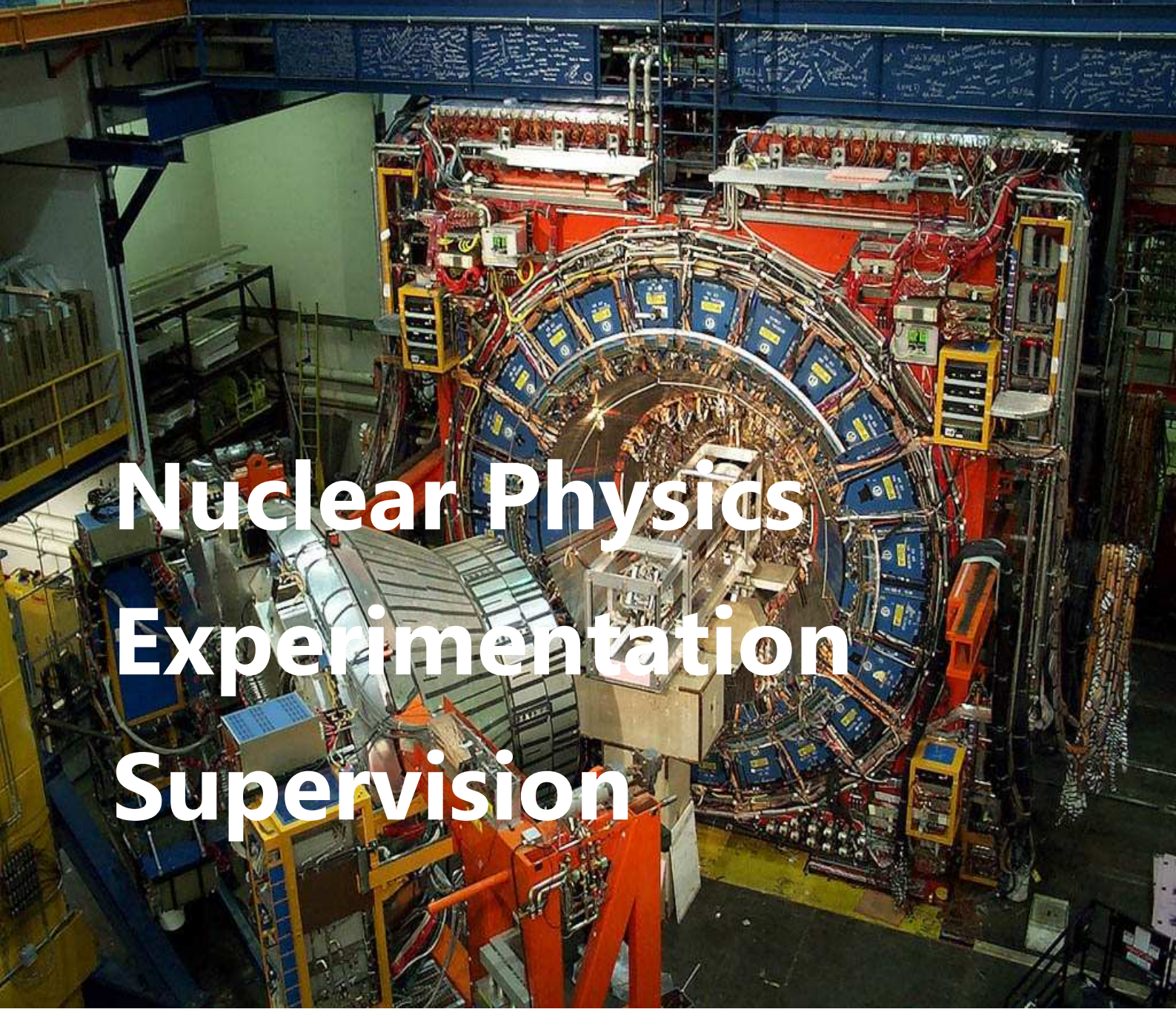


Nuclear Physics Experimentation Supervision

The National Institute of Nuclear Physics (INFN) inventors of the DAFNE particle accelerator use Movicon supervision for system control.

The National Institute of Nuclear Physics (INFN) is the Italian research agency dedicated to the study of the fundamental constituents of matter and the laws that govern them, under the supervision of the Ministry of Education, Universities and Research (MIUR). It conducts theoretical and experimental research in the fields of sub-nuclear, nuclear and astro-particle physics. All of the INFN's research activities are carried out within a framework of international competition, in close collaboration with

Italian universities based on consolidated partnerships spanning decades. Fundamental research in these areas necessitates the implementation of cutting-edge technology and instruments, developed by the INFN at its laboratories in collaboration with industrial organizations. The National Laboratories of Frascati (LNF) is INFN's oldest and biggest Italian research center for nuclear and sub-nuclear physics with accelerator machines. The LNF began construction back in 1955 during a period of strong growth for particle physics. In the years leading up to this period, physicists had been investigating the structure and transformations of nuclei and were just beginning to study the nature of their components. Experiments on cosmic radiation had also revealed the existence of new particles, which are absent in ordinary matter. INFN delegated LNF the task of building particle accelerators to investigate the structure of the atomic nucleus in their laboratory in order to produce new forms of matter. Since then, the LNF have been involved in all areas of INFN research: physics of accelerators, nuclear and sub-nuclear physics, cosmic radiation physics and physics with synchrotron light. Currently 362 personnel work at the Laboratory as researchers, technologists, technicians and administrative staff. In addition, they also collaborate with another 450 Italian and foreign researchers in various scientific activities. LNF's main strength is its capacity and know-how to build particle accelerators. Research began on the synchrotron in 1957 in order to create a prototype of collider rings to study the collision of matter and anti-matter. This was achieved within a year with the first ever AdA, an accumulation ring known as an electron-positron particle collider. This was used for accumulating dense beams of orbiting particles (or projectiles) in order to obtain a significant number of reactions to create energy. This invention was replaced by ADONE, a more sophisticated electron-positron collider. This was then phased out with the current DAPHNE, which has successfully achieved world record instantaneous luminosity at low energy level.

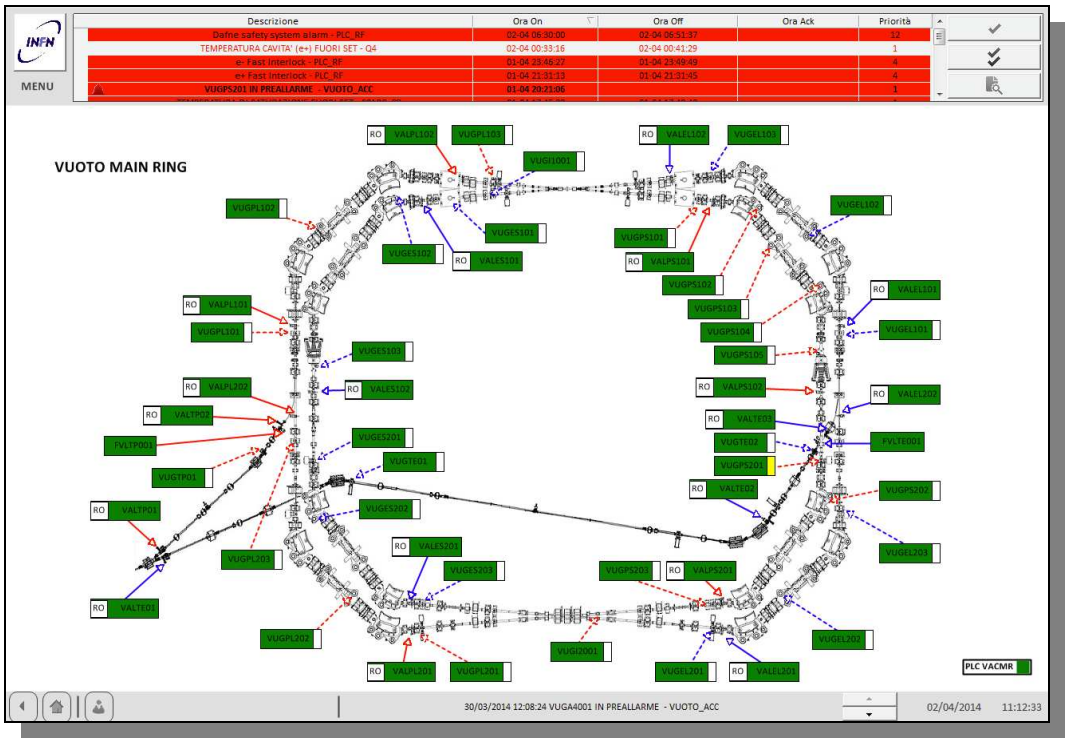
The DAFNE Particle Accelerator plant at the Nuclear Physics research agency in Frascati uses the cutting-edge Movicon supervision system for maximum security and precision.

The DAFNE particle accelerator

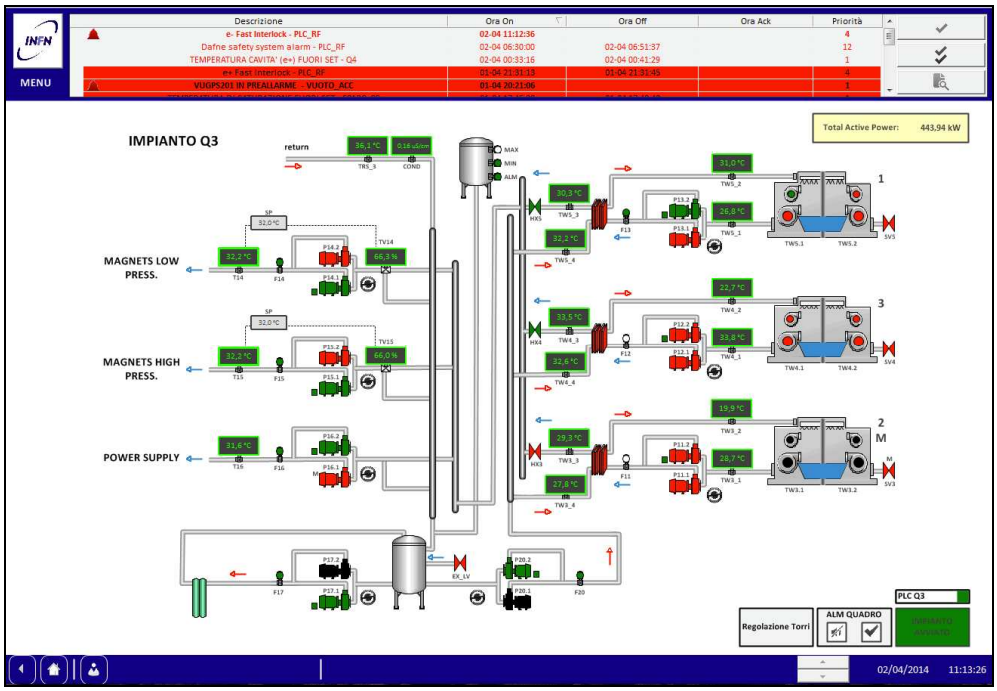
DAFNE, (DAΦNE) acronym for Double Annular Φ Factory for Nice Experiment, is one of the major particle accelerators in the world dedicated to the study of sub-nuclear physics and phenomenon that have governed the first instances of life in our universe. The accelerator is hosted at the National Institute of Nuclear Physics (INFN) laboratories. This research agency was founded in the 50's to continue the fundamental research of Enrico Fermi and students of the via Panisperna who made Italy famous in this field of research at a worldwide level.

DAFNE is a Phi-factory that produces Φ particles by colliding electrons with positrons (the anti-matter of electrons) by rotating two 30 meter diameter rings in opposite directions with beam energy up to 510 MeV. The Φ particle is very unstable and decays into other low mass particles which include the "K" mesons that have "S" (strange) quark contents, one of the main building blocks of nature and denominated so for its anomalous behavior. The main task of DAFNE is to study this decay using the KLOE calorimeter to detect and count the particles produced in the interaction stage in order to reveal the violation of the charge parity symmetry principle (CP-Violation) with top precision. This principle is linked to the energy transformation into matter and anti-matter and has implications on theories relating to the origin of the universe.

DAFNE's challenge is make sure that research carried out on this rare phenomenon is done with the greatest of accuracy.



The supervision system where researchers control all the DAFNE Particle Accelerator parameters by using, for example, graphical representations of the main ring vacuum system.



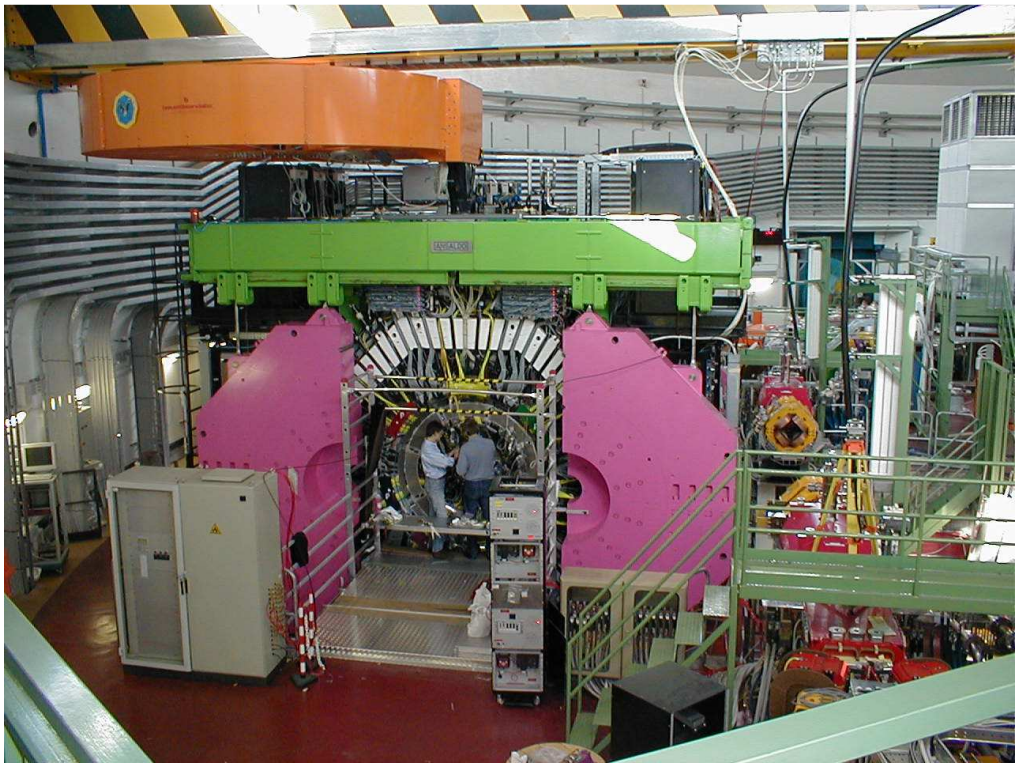
An important and complex system such as the Particle Accelerator must have a fast performing, accurate and reliable supervision system. Movicon was chosen for this.

Taken from an engineering stand point this project requires a system that is absolutely accurate and reliable. It has to be capable of functioning for long periods of time (months even years) without any interruptions, to collect useful scientific data.
This complexity results from a synthesis of skills, which in addition to accelerator physics include mechanical engineering, vacuum, radiofrequency, magnets, power electronics, signal electronics, controls, diagnostics, information technology, cryogenics, electrical and mechanical systems; each one reflected in a functional subsystem to others.

The auxiliary system revamping challenge

The accelerator, designed in the 90's and in operation since 1999, has undergone various updates for improving performances both in terms of physical (number of collected events useful for research objectives) and in terms of energy efficiency. In order to increase the reliability of this complex system, the auxiliary automation system has recently been revamped due to increasing and frequent malfunctioning that prohibited the prolonged functioning of the accelerator.
In a complex system such as DAFNE, the malfunctioning of a component causes not only a loss in scientific production but also energy consumption of those systems that have to remain in operation which would otherwise need several working days to restart all the accelerators.
Some systems experiencing critical problems can take up to several weeks to reassume full operation after problem has been solved.
Furthermore PLC and control system spare parts were becoming hard to find on the market. As a consequence this would critically compromise operations in those systems involving devices that lacked replacements for malfunctioning components.
The challenge to probe deep into the system structure and contemplate engineering logic from a different perspective, which was largely based on past experience of those operating the systems since they were installed over twenty years ago, has not only enabled targeted and cost effective

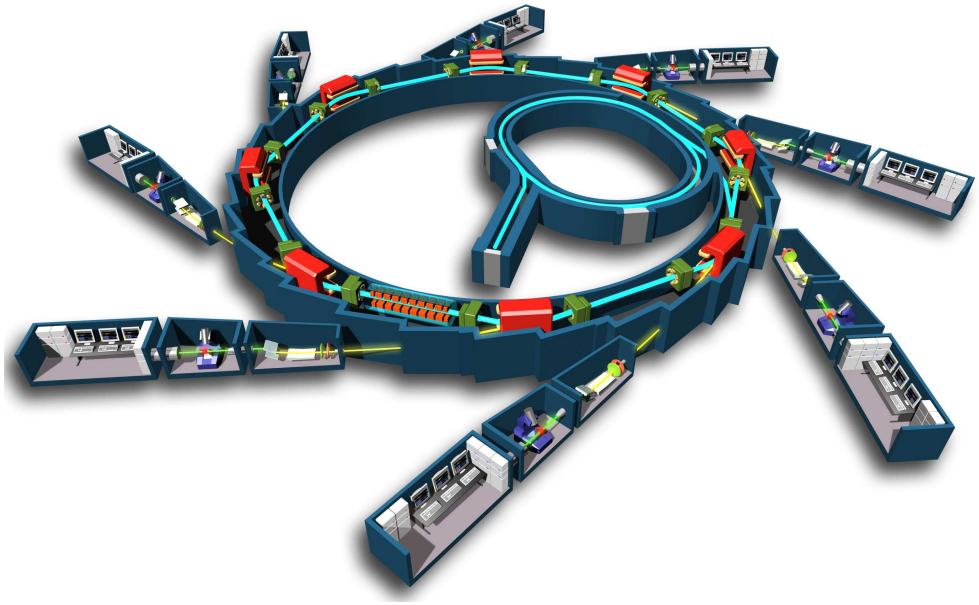
interventions to be implemented but also the opportunity to enrich their knowledge of the system. Knowledge that had been side tracked during daily routine work. This gave them the chance to detect and remedy repetitive problems that were difficult to find and resolve during ordinary maintenance checks. The project to replace the PLCs and the supervision system of all the DAFNE systems was conducted by inhouse technical staff in collaboration with System Integrators from Lazio, among which included Automate Srl. This involved performing a critical analysis of the research agency's needs to establish the best technical and cost effective solution comparable to security maintenance costs of the existing system. Results from the preliminary analysis enabled the engineers to optimize and distinguish which hardware is fundamentally necessary to the correct running of the various systems and avoid wasting funds on unnecessary automation devices and equipment.



The DAFNE Particle Accelerator automation system is based on then high performing PLCs connected to each other in ethernet and interfaced locally with four HMI Embedded Movicon workstations with a Main SCADA Supervisor also based on Movicon. Furthermore, the system is accessible through the web (e.g. by using iPAD), made possible by the Movicon Web Client technology.

The new system is comprised on 10 Schneider and 1 Siemens S7 PLCs in ethernet network, which constitutes the core of the automation system together with a SCADA server developed on the Movicon 11 platform. There are also four HMI operator panels (based on Movicon CE) installed throughout the various control rooms within the Frascati research centre so that the systems can be managed locally.

This new system not only ensures all the previous service and system performance at all levels, it also provides enhanced robustness and reliability at automation level, low energy consumption, less electrical and mechanical stress of equipment, new maintenance tools and a greater level of ergonomics and man-machine interface operativity. A great effort was made in optimizing the systems both in terms of electrical and automation engineering.



A generic scheme of the circular rotating particle accelerator whose magnetic field (needed for bending the trajectory of the particles) and the variable electric field (which accelerates the particles) are synchronized with the beam of particles.

The electrical revamping, implemented by Automate Srl, has not only made it possible to replace old PLCs but also ad hoc optimization of each field signal board. Assisted by the Frascati INFN technologists and technicians it was possible to accomplish important reverse engineering geared towards the actual operational needs of the systems by streamlining the complexity that had accumulated over the years due to accelerator modifications and updates. This was done by eliminating those control systems that had become unreliable if not obsolete.

In addition the automation logic has also undergone a similar process of engineering that entailed the programming of algorithms geared towards reinforcing process control robustness and service continuity. This was also done with the aim to minimize and monitor energy consumption of the systems as well as the electro-mechanic stress endured by equipment in order to reduce installation and maintenance costs.

Automate Srl was able to interpret the ideas, requests and needs of the research agency successfully. Using their know-how they were able to develop automation logic and cutting edge man-machine interface tools specifically tailor made for INFN. They achieved this by using Movicon a developer tool which they found to be most suitable for their various integrator needs. By making full use of the Movicon features they were able to standardize the user interfaces between SCADA and HMI by standardizing the skills needed for managing the systems. Ultimately, this made it possible to optimize

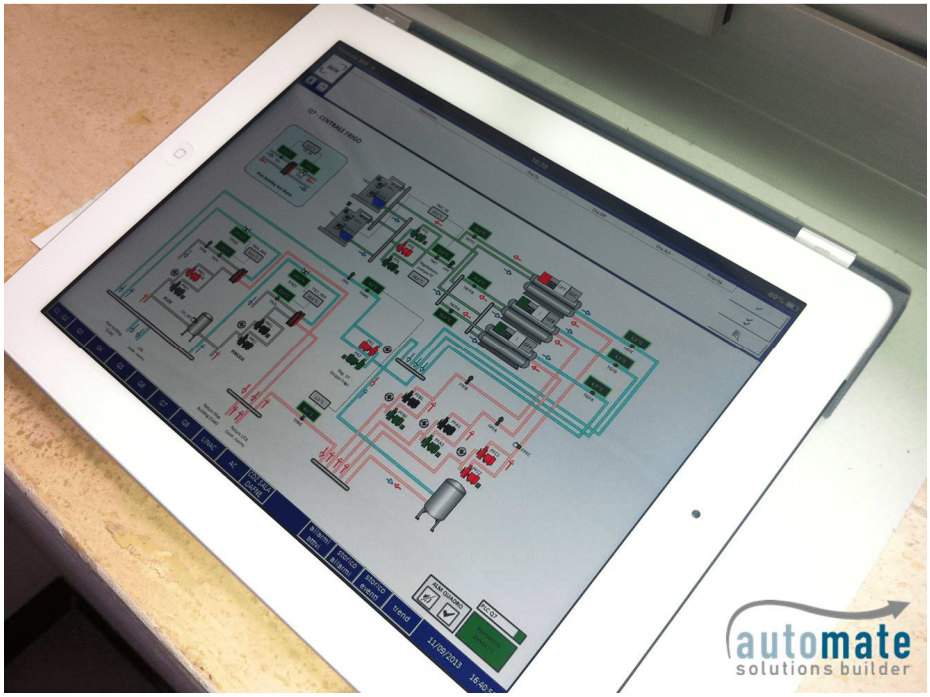
and reduce supervision system development times.

Movicon is in fact deployed as the supervision control system of the auxilliary DAFNE particle accelerator systems that include:

- Control systems for the DAFNE Main and Damping Ring cooling systems;
- DAFNE vacuum control system;
- Magnet overheating protection systems;
- Radio frequency systems;
- DAFNE control room air conditioners;
- Computer room air conditioning.

The main revamping efforts were focused on the accelerator's cooling system. In fact the major part of the equipment (magnets, convertors, RF structure), is cooled and controlled by means of a circuit using distilled water obtained by osmotic process that is managed from three control rooms and supervised by Movicon. The heat is disposed through cooling towers using heat exchangers operated with three-way valve and temperature sensor system.
It is crucial that constant extreme temperatures are kept monitored and controlled with little variation. In order to function properly, the temperature of a major part of the equipment needs to be controlled with great accuracy so that they do not oscillate more than half degrees Celsius at a time. Meanwhile the radio frequency cavities, used for providing energy to the particle beam, are controlled at a steady temperature within a tenth of a degree range.
A refrigeration system is then used for air conditioning and cooling the electronics of highly critical equipment.

The particle beam is confined to an ultrahigh vacuumed chamber which is also controlled and monitored by Movicon for leaks, pre-alarm states and alarm events. A subsystem comprised of 45 vacuum gauges and 41 sectioning valves (including manual valves, electro-pneumatic and rapid valves), controls and isolates the section where the leak is detected.



The Movicon Web Client technology enables Researchers, carrying out experiments with the DAFNE Particle Accelerator, to connect to the system using APPs for iPhones and iPads.

The energy impact of the new control system

In the last few years the Frascati INFN and its team of technicians have enforced a policy to save energy that also played a dominant role in the project to revamp the control system of the DAFNE particle accelerator sub-systems.
As a result of the various interventions carried out on the accelerator, energy consumption has been reduced from the initial value of 5.9 MW to the current value of 3.3 MW.
Subsequently the significant cut in electrical bills has managed to exceed the high increase rate in KWh costs over the last few years.
Not only does this energy reduction have a positive effect on the environment it has also contributed to sustaining the accelerator running costs that are largely electrical.
The realization of the new control system in addition to pinning down and resolving a series of major problems has promoted greater reliability in managing the systems.
Another great accomplishment was not only getting the cooling system to function with fewer pumps and vapour towers than before but to make it more reliable. In addition, optimization logic has been implemented with the aim to reduce consumption costs.
As an overall result of using the revamped cooling system the DAFNE research centre has managed to save an average of 70kW. This means that for a system working 6000 hours a year they managed to get their investment returned within one year only.

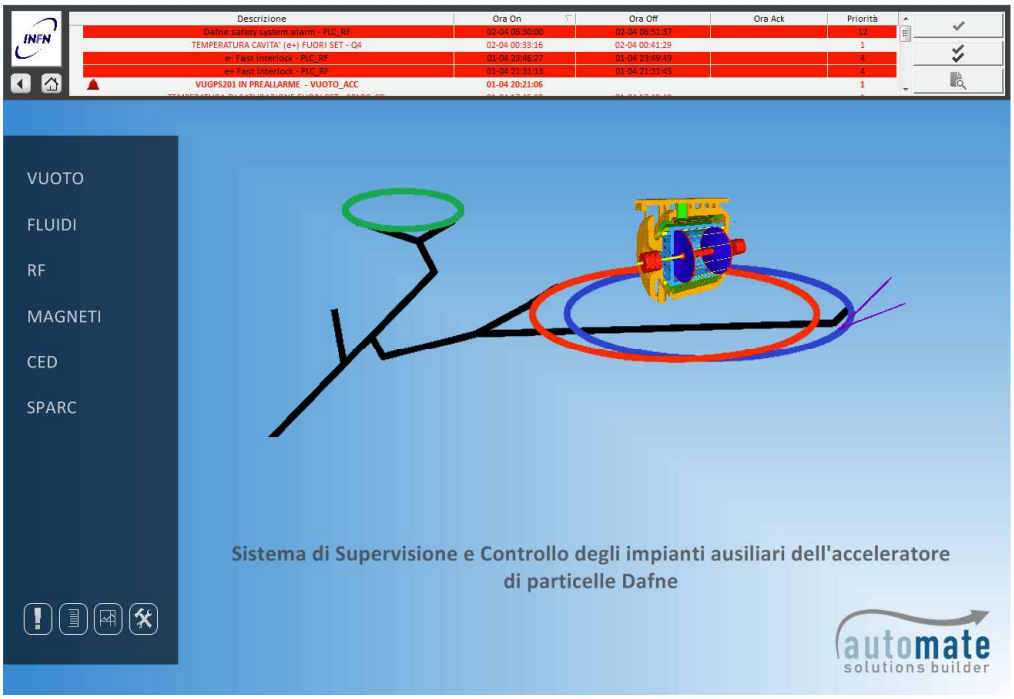
The role of Movicon

All the system situations are represented by Movicon through Trends, Alarms with filters by zone and causal data. It also performs analysis on historicals using the DataLogger and DataAnalysis tools. The data is collected from the different devices using the Multidriver and especially with Shared memory mode to communicate with the HVAC system of the test facility which uses non-standard air conditioning machines. The tools provided by Movicon can easily interface with old equipment and propriety protocols. The operators and maintenance workers who have system access now use four web clients to keep everything under control and perform operations or interventions directly where the critical points are detected. The supervision system of the DAFNE particle accelerator auxiliary systems is also connected to other systems that have been installed on the supervision platform. These include systems such as the HVAC of the CED and the Free Electron Laser (FEL) clean room system used for the SPARC project which is independent from the DAFNE project.

Conclusion

In conclusion, INFN has achieved optimal results with revamping its control system and implementing the Movicon supervision application. One of the revamped features involved obtaining continuous operation of the accelerator during maintenance interventions and system management (eg. exchanging pumps, optimizing the number of components in service in function with the environmental conditions and workload). Multiple system working conditions have been revised, re-implemented, tried and tested to prove more resilient to a large number of possible malfunctions and reduced or unavailable subsystems.
The technological update with added centralized supervision in the control room along with web access for operators possessing different profiles and work duties has managed to abolish downtime events.

The new supervision system has been designed with the aim to be used as a tool to aid system technician specialists, physicists and machine operators (i.e. the accelerator) who do not have specific system skills. The skills that they do have can now be used together and put into use in other systems in the accelerator control room to improve performances and detect any problems with greater ease. Information that was only available to field specialists can now be used by physicists along with thousands of other parameters to manage the accelerator. Ultimately and just as important is the reduction resulted in electric power consumption. This achievement also contributes as one of the goals predefined by the Institute. The work carried out is undoubtedly an Italian masterpiece considering that all collaborators in this project are Italian: INFN is an internationally well-known Italian research agency, Progea srl is a leading Italian company in software platform for automation worldwide and Automate Srl are leading system integrators in the industrial automation sector based in Rome.



INFN has obtained optimum results with revamping their control system which has been made possible by implementing Movicon supervision

Ing. Merco Roberto
Automate Srl