Visual programming of the regulation and supervision of the new intensive care unit at the Cardarelli hospital in Naples

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Abstract. This article aims to describe the installation of advanced ventilation systems in some departments of the most important hospital in Naples. Although these are complex and above all critical control logics, it was the installer himself who carried out all the installation, integration, programming and testing activities independently. In addition, in the event of evolving requests from medical personnel or maintenance of system components, the installer can adapt the logic, accordingly, without al-ways having to contact the manufacturer of the controllers. This means being able to act both in complete autonomy and being able to respond quickly to the customer's re-quests. Not only energy efficiency but also adaptability to changes in an autonomous and fast way.

1 The requests from the hospital

For some years now, the need to be able to adapt intensive care units to areas dedicated to infectious patients has emerged in a striking way. During the recent COVID-19 pandemic, in fact, many cases of contagion occurred precisely in places where patients are in critical condition for other reasons and therefore further infection can degenerate with fatal outcomes.

The so-called "Decreto Rilancio" of 2020 [1] in article 2 "Reorganization of the hospital network in the COVID-19 emergency" paragraph 2 reads as follows:

"*The regions and autonomous provinces are planning a redevelopment of 4,225 beds in the semi-intensive area, with related plant equipment suitable for supporting ventilation aid equipment, through the adaptation and renovation of medical area units,* ***providing that these stations can be used both in the ordinary regime and in the high-intensity infectious treatment regime****. In relation to the trend of the pandemic curve, for at least 50 per cent of the beds referred to in this paragraph,* ***the possibility of immediate conversion into intensive care beds is envisaged, through the integration of the individual stations with the necessary ventilation and monitoring equipment***".

The Cardarelli hospital in Naples (Figure 1), and in particular the UTIC (Cardiology Intensive Care Unit) and Electrophysiology section at the Hospital of National Im-portance (A.O.R.N.) also had to adapt to the legislation but with an additional sensitivi-ty: it is necessary to ensure timeliness of action also by the doctor, which means ease of management and monitoring of ventilation systems. This must also include the plant operator, who must be able to act independently of the manufacturer of automation solutions for building technological services.

Figure 1 - The "Antonio Cardarelli" Hospital of National Importance

The "Antonio Cardarelli" Hospital of National Importance is a large provider of health services, which is responsible for important functions and responsibilities, in the exercise of ensuring health care over a large territory, which embraces a catchment area extended, in addition to the city, also to the province and Campania, and represents a point of reference for other regions of Italy, especially in the South.

The "A. Cardarelli" Hospital of National Importance and High Specialization has acquired the role of national importance, based on the recognition of function attributed to the Prime Ministerial Decree 8-4-93 and with Decree No. 12255 of 22-12-1994 of the Campania Region.

The "Cardarelli" Hospital plays a leading role in emergency healthcare: it is in fact home to a second-level Emergency-Acceptance Department, ensuring first aid services in multiple specialties. It is also home to the Major Burns Center, the Poison Control Center and the Center for Liver Transplants (Regional Emergency Centers); there is also the recently established Hyperbaric Therapy Center.

The "A. Cardarelli" company also stands out for its specialist elective activities in the medical and surgical area, thus representing a reference for the regional health network

The care activity produces a high number of ordinary and day-hospital admissions per year, on average exceeding 90,000, as well as outpatient services within the various specialties.

The company's building renovation and technological modernization works, currently underway, make it possible to provide operators and users with a structure that is always in step with technological advances and progressively adapted to the best of the patients' comfort needs.

The "A. Cardarelli" hospital, located in the heart of the hospital area, is structured "in pavilions" and occupies, in total, an area of 250,000 square meters. Of these, 50,000 square meters are represented by buildings, and the remaining 200,000 by tree-lined avenues and pine forests that in fact constitute a real "green lung".

Of the 21 existing pavilions, built in different eras from 1927 to 1990, fourteen are intended for diagnosis and treatment activities, and the remaining seven for technical and administrative services

In addition to the internal road network, the company's buildings are aggregated by underground connections for technical and service activities, which develop in correspondence with the large surface of the hospital, constituting a real "road network" for the operators.
A heliport is located within the surface of the Company, which is the fulcrum of rapid transfers in the context of intra- and extra-regional emergencies, where air ambulance intervention is required. The structure of the heliport, equipped with the most modern technical control and safety tools, allows landing and take-off even at night.

1.1 The HVAC components of the hospital's ICU department

The components to be adjusted and monitored are:

- Two multi-purpose refrigeration units (Figure 2)

Figure 2 – The rooftop heat pumps of the UTIC section

- Two AHUs (Figure 3) on the roof for the ICU (Figure 4) section and the ELECTROPHYSIOLOGY ward

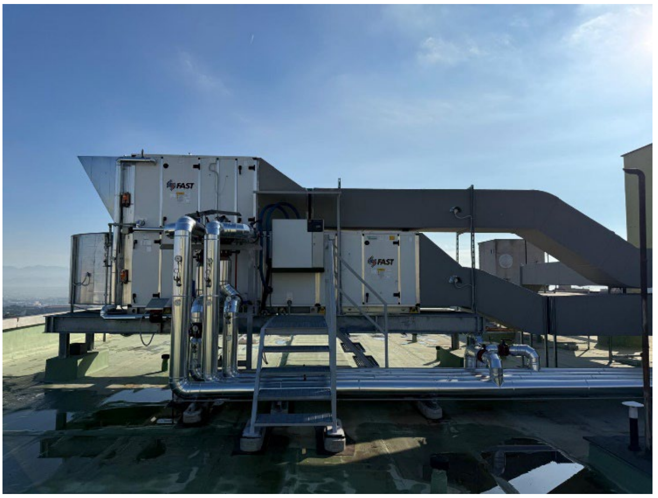

Figure 3 – The AHU rooftop of the UTIC section

- Variable Air Volume boxes with reheat coils for the wards

Figure 4 – One of the ICU rooms, in the background there is a VAV box

Automation must control components to maintain setpoint values in terms of:
- temperature,
- humidity,
- air pressure,
- water flow rate,
- air quality.
- Overpressure or depression of the premises according to the doctor's re-quests

1.2 Purpose

1. If the ward director must receive a potentially infectious patient who therefore needs treatments for which he must not contaminate the other hospitalizations, the doctor must be

able to act on the regulation system in such a way as to transform a clean room into a biological room in real time.
2. The monitoring system must detect any anomalies in real time both to doctors and nurses, and to the operators dedicated to the technical maintenance of the system.

2 Hardware and software implementation methods

In front of each room there is a display, THC 002 (Figure 5), which presents the fundamental parameters of the room, including:

- set point and relief temperature and humidity,
- overpressure or depression of the environment,
- detection of any alarms.

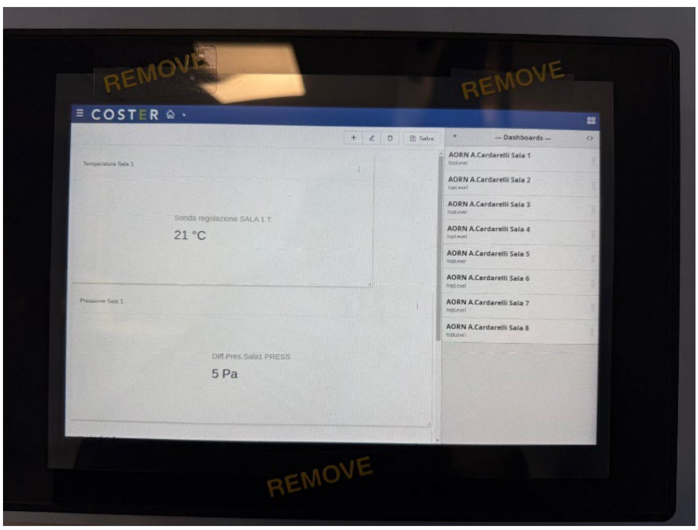

Figure 5 – Main screen of one of the THC 002 interactive room monitors

The display is connected via the ModBus bus to the Edge EHC 602 device. ZBC 862 controllers are connected through the BacNet network, which deal with both AHUs, heat pumps and VAV boxes in the room. The Edge controller is also equipped with BMS/EMS; therefore, in addition to connecting fieldbuses (ModBus, Knx, M-bus, Bac-Net, etc.), it can behave like a server PC, avoiding an additional device to be managed at the IT level. The system architecture is shown in Figure 6.

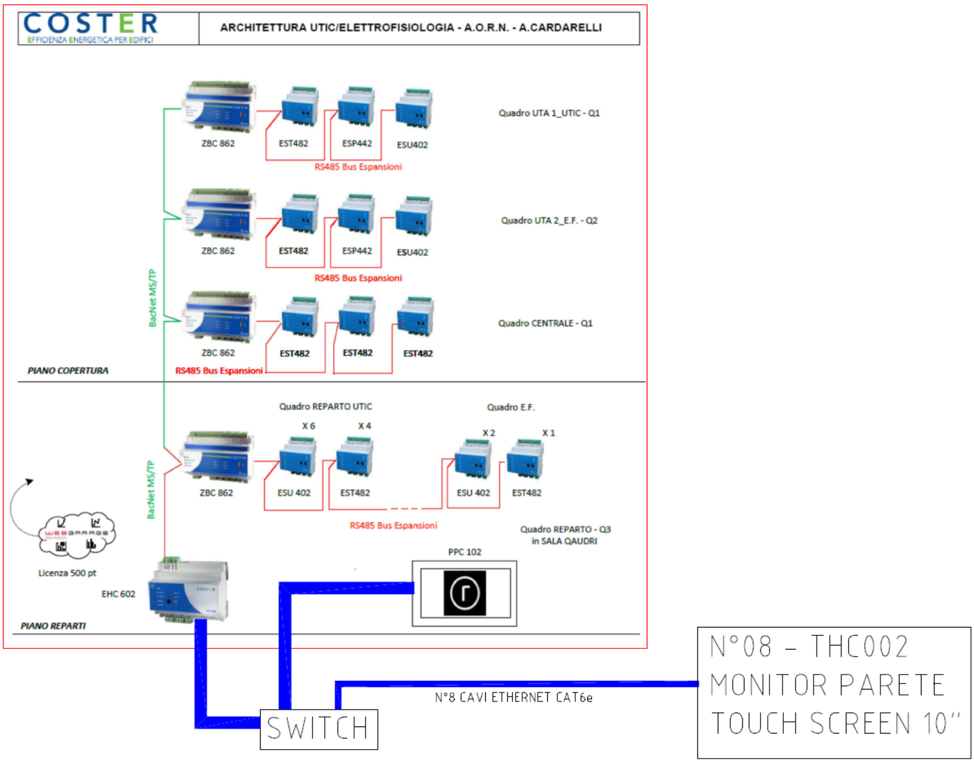

Figure 6 – System Architecture

The proposed BMS system will be responsible for the management of the following areas:

- monitoring and control of the Roofing Plan Technological Centre,
- AHU UTIC monitoring and control and Electrophysiology,
- monitoring and control of UTIC and E.F. department units,
- interfacing and embedding third-party equipment.

The Technological Centre is identified as a set of equipment used for the genera-tion and distribution of fluid at the service of the various users such as AHUs, reheat coils, etc.
The architecture of the BMS is based on distributed intelligence logics, i.e. each controller contains the logics for controlling the system, this allows, in the event of a failure of a single controller or expander, that the system continues to operate with the logics set on the remaining controllers.
Specifically, there are three digital controllers on the roof with their respective expanders divided by AHU UTIC, AHU Electrophysiology and heating and cooling unit.
The controllers of the "ZBC" series are freely configurable devices specific for HVAC systems via the CosterCAD application [2].
The communication protocol is BacNet, which allows a higher communication and data transfer speed than other protocols, specific for use in the hospital sector where it is necessary to control flow rates and pressures in real time.
For the Roofing Floor Technology Centre, the control/monitoring of:

- heat pumps,
- AHU,
- water circulation pumps,
- motorized 2/3/4-way valves, with mixing, diverting or shut-off function,

- safety thermostats, pressure switches or flow switches,
- temperature, humidity and pressure sensors.

For what is described above, the acquisition and management of the main param-eters such as

- reading of measurements of the values of temperatures, pressures, and so on,
- acquisition and reporting of statuses and alarms,
- setting the time schedule of the main equipment,
- analogue and digital controls suitable for the management of fans, dampers, valves, etc.

For the Department Floor Users, the control/monitoring of:

- reheat coils,
- VAV,
- motorized 2/3/4-way valves, with mixing, diverting or shut-off function,
- safety thermostats, pressure switches or flow switches,
- temperature, humidity or pressure sensors,
- read-only touch display screens.

For what is described above, the acquisition and management of the main param-eters such as

- reading of measurements of temperature, humidity, pressure, and so on,
- acquisition and reporting of statuses and alarms,
- setting the time schedule of the main equipment,
- analogue and digital controls suitable for the management of fans, dampers, valves, etc.

Communication between the devices takes place via a backbone up to the ward floor, where an additional ZBC is positioned with expanders divided into the ICU department and the Electrophysiology department, which have the task of detecting temperature, humidity and pressure from the rooms and driving the VAVs and dedicated reheat coils.

Also on the ward floor is the EHC 602 communication network that optimizes communication between the controllers and manages and monitors the field through the THC 002, which will be positioned in every room where the VAVs are present and make the temperature, humidity and pressure parameters available to the user to view.

The EHC 602 Edge device is licensed, so it can work stand-alone or networked and is therefore equipped with a web interface.

The WEBGARAGE license is 500 points, of which 100 are historic.

In addition, there is a fanless panel PC (Figure 7) from which you can operate in the system through dedicated graphic pages.

https://doi.org/10.1051/e3sconf/202671004001

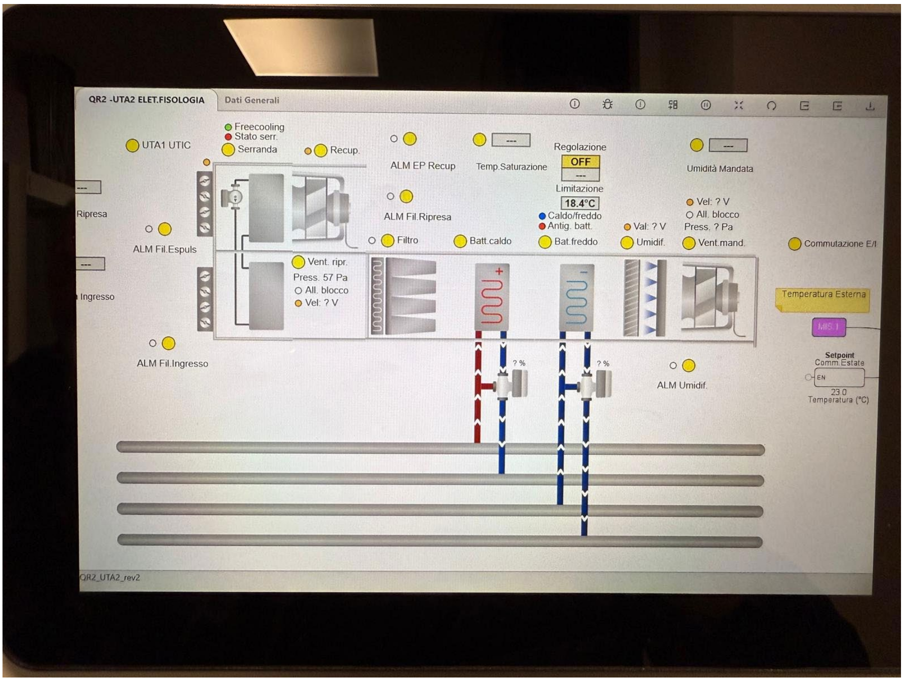

Figure 7 – The PPC 102 panel PC for the web interaction with the BMS System

The WebGarage BMS system also provides, on request, the monitoring and control of the supervision equipment used for serial interfacing via the ModBus RTU RS485 communication protocol, ensuring the acquisition of the main parameters such as:

- temperature,
- statuses and alarms,
- time scheduling,
- analogue and digital controls,
- other variables deemed useful for the purpose.

The system is designed to be able to integrate data from third-party systems or devices (existing controllers, lighting control, measuring instruments, etc.) for which one of the most common open standard protocols such as ModBus RTU or TCP, M-Bus, BacNet MS-TP or IP is available.
In addition, through the implementation of appropriate protocol conversion gateways it is possible to supervise any type of device (KNX, DALI, and more).
The architecture of the supervision system, with distributed intelligence, with native features highly devoted to scalability and expandability, allows you to imple-ment a robust, efficient and technologically advanced solution, always in line and up-dated with the evolution in the IT environment.

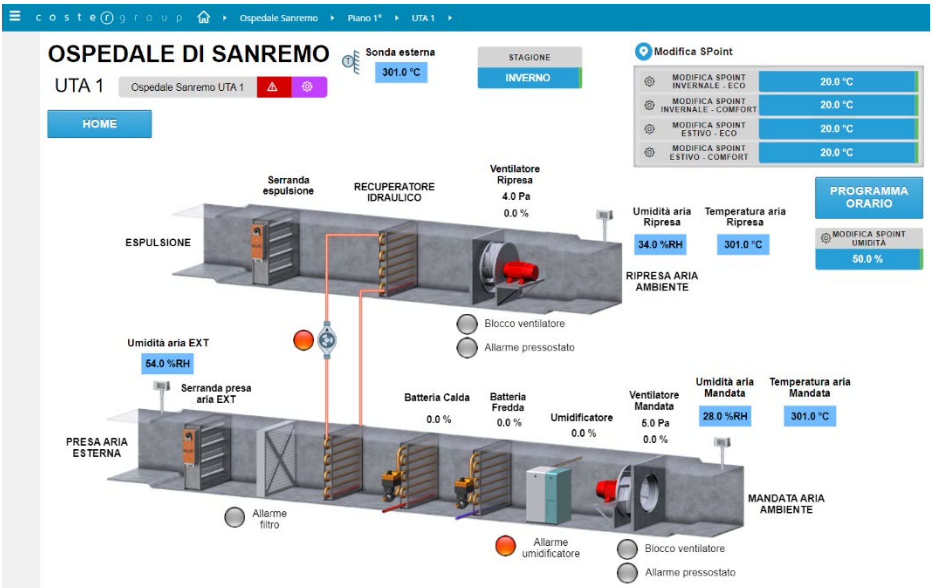

Figure 8 – A possible alternative view of the AHU, via advanced graphical WEB pages

WebGarage integrates the basic functionalities of a Building Automation & Control System (BACS) that supervises and controls HVAC systems while adding the additional benefits of a Building Operating System to govern, visualize and enhance relevant data: an example of a graphic view is shown in Figure 8.
WebGarage is based on the Haystack standard and ensures advanced functionality and potential thanks to tagging and data modelling, making it easy to create dashboards.
Advanced analytics features are also included to support diagnostics and optimize performance, as well as openness to all possible integrations of third-party devices and solutions from the Haystack collaborative community.
The custom graphic pages with the association of physical points with advanced and customizable graphic components guarantee intuitive and immediate control of the performance of the systems.
All the operating logics of the supervision system are installed on each "zone" controller in order to structure a distributed intelligence system designed to ensure maximum functionality and safety even in the event of a lack of communication.

3 Implementation methods: logic through visual programming

The operating logics provide for the control and regulation of temperature, humidity, pressure according to the design set points by means of supply air temperature probes and pressure transducers for the AHUs on the roof.
In addition, the control and control of two heat pumps and the hot and cold fluid pumping system are regulated with reference to the outside temperature and fluid temperatures. For the intensive care rooms on the fourth floor of the ICU, the operating logic must keep the temperature constant by means of the respective reheat coils, above the overpressure of +10 Pa for six chambers, and for two chambers the depression -10 Pa. The control is ensured by reading the pressure transducers of the pressure differential between the chambers and the corridor, which modulate the VAV-type dampers in-stalled on the respective return channels, to guarantee the design set points. The five semi-intensive care rooms of the electrophysiology department are regulated only by temperature by modulation of the 2-way

valves placed on the respective reheat coils. The relative humidity of the ICU and electrophysiology environments is detected by means of analog probes installed on the general supply air ducts of the AHUs. In the rooms of the intensive care unit, touch screen monitors are installed on the wall for the display of temperature, humidity and pressure only. The thermal power plant is auto-mated with a controller and some expanders that are virtualized in the visual program-ming software called CosterCAD. [2]
From the CosterCAD screen it is possible not only to virtualize the devices in the electrical panel, but also to program the logics through preconfigured modules.

Figure 9 – Physical view of the electrical panel with controllers and expansions

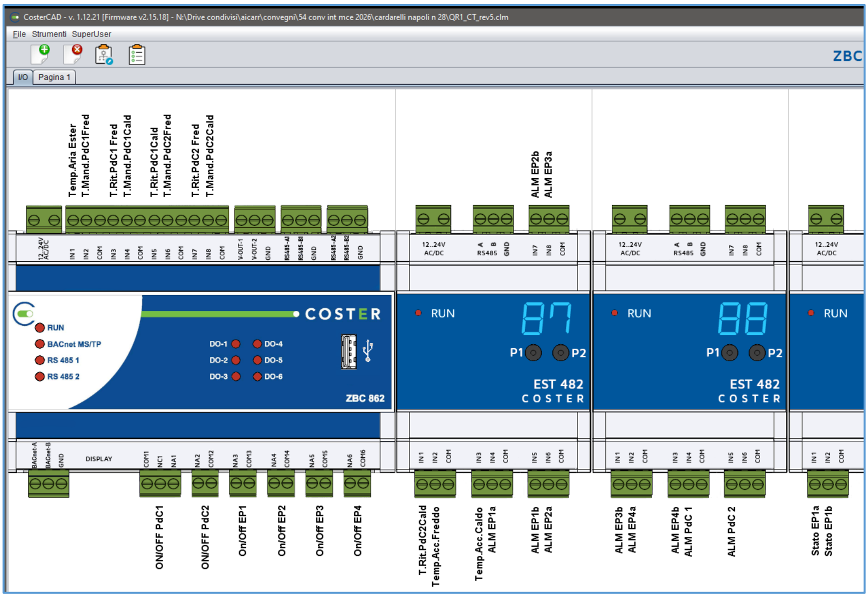

Figure 10 – Virtualized Vision with CosterCAD, very close to the real panel

In addition to the virtualized view of the equipment that is used to assign and identify connections in terms of digital/analog inputs and outputs, CosterCAD builds programming from the description of the components in the field that are added as pre-configured modules.

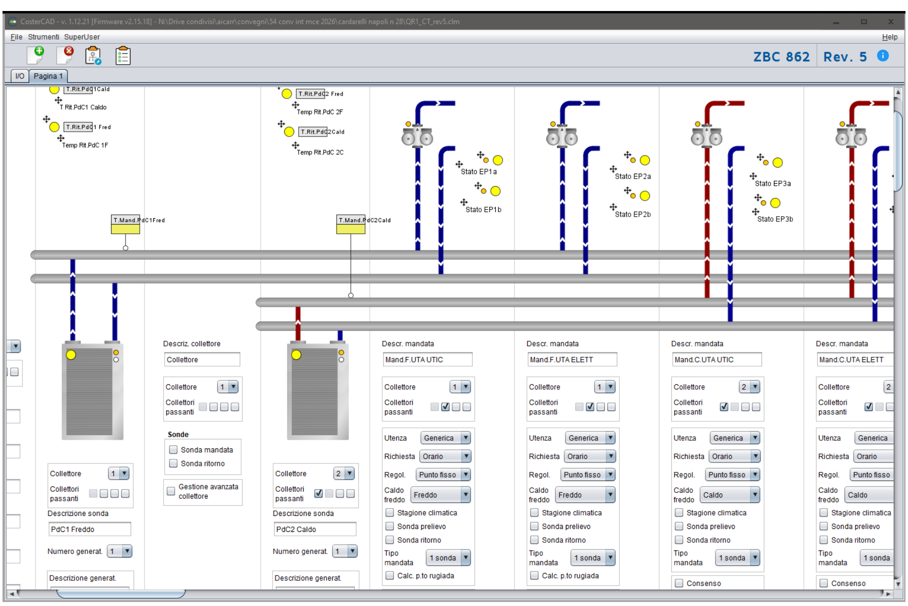

Figure 11 – CosterCAD virtualized view of logic in modular form

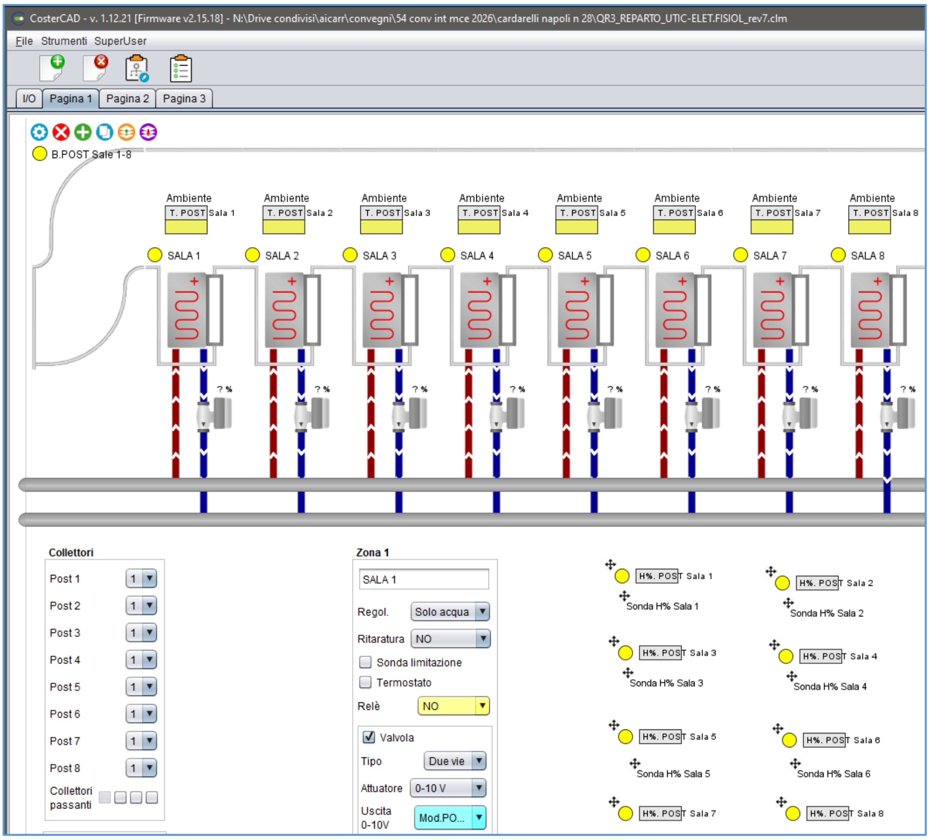

Figure 12 – The virtualized view with CosterCAD of logics in modular form, the heat exchangers of the VAVs

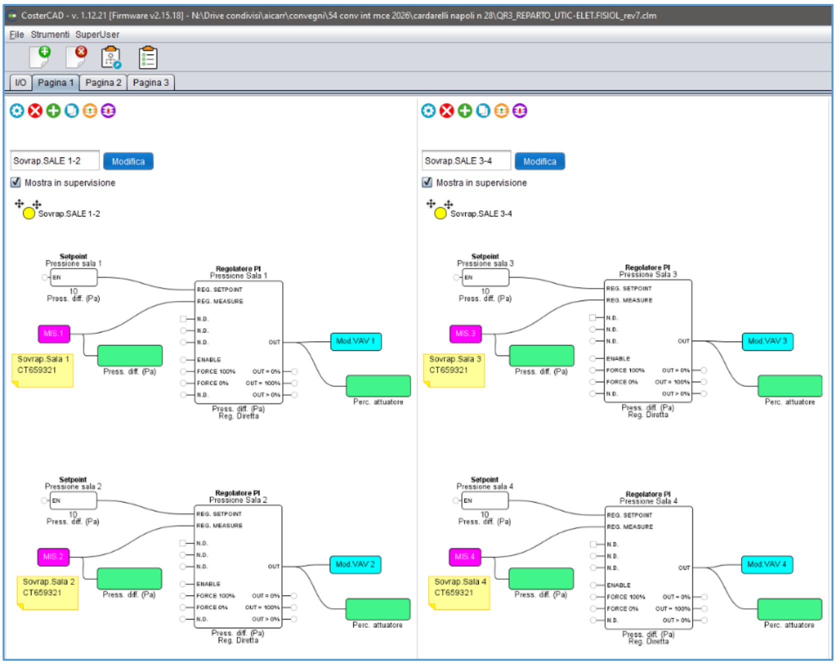

Figure 13 – The virtualized view with CosterCAD of the logic in the form of a diagram for the control of differential pressures in the rooms

4 Conclusions

This implementation of the functions imposed by law is not so innovative. What is really innovative is the possibility of the installer to modify the programming logic completely independently without necessarily having to contact the manufacturer of the hardware components. The installer does not need to know any programming languages, but simply he must know how to aggregate the modules correctly. The modules are components of well-known systems such as heat pumps, boilers, discharges, AHUs, inertial storage tanks, and much more. Ultimately, this approach shifts the paradigm from manufacturer-dependence to installer-autonomy, significantly reducing maintenance downtime and operational costs while ensuring that the hospital can adapt its critical environments to emerging clinical needs in real-time. The CosterCAD programming software can be downloaded by anyone from the website of the controller manufacturer for free.

References

[1] Decree-Law no. 34 of 19.05.2020 "Decreto Rilancio".
[2] CosterCAD training video: https://youtu.be/ohvVSu8-Cgw