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Study of variable refrigerant flow systems: an alternative to traditional air conditioning

Studiul sistemelor cu flux variabil de agent frigorific: o alternativă la climatizarea clasică

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Abstract. *Variable refrigerant flow systems offer significant advantages over traditional air conditioning systems. They enable individual temperature control for each indoor unit, providing superior comfort compared to the uniform settings of conventional systems. VRF optimizes energy efficiency by adjusting the refrigerant flow according to overall demand, thus preventing excessive energy consumption. Due to their scalability and easier integration into modern buildings, VRF systems represent a highly efficient and adaptable solution for contemporary climate control.*

Key words: Variable, efficiency, systems, refrigerant

1. Introduction

Sustainability in building design depends on implementing systems that preserve future access to resources. Ensuring efficient maintenance of comfort conditions poses challenges for air conditioning systems, particularly during transitional seasons like autumn and spring. Smooth transitions between heating and cooling operations are often based on preset external temperatures.

2. Theoretical aspects

The VRF systems (Variable Refrigerant Flow) are similar to a normal domestic air conditioning system, but designed on a larger scale. A VRF system consists of one or a group of outdoor units that supply refrigerant through a piping network connected

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to multiple indoor units. Each indoor unit, by opening its expansion valve, can access the refrigerant for either cooling or heating purposes. Each individual indoor unit determines the capacity it needs based on the actual indoor temperature and the desired (set) temperature. The total demand from all the indoor units determines how the outdoor unit regulates the volume and temperature of the refrigerant. VRF is a technology that adjusts the refrigerant volume within the system to match the exact needs of the building. To maintain the set temperatures and automatically stop operation when no one is present in the room, only a minimal amount of energy is required. VRF systems are carefully engineered, featuring single or multiple compressors, multiple indoor units, and advanced refrigerant management and control components. They offer flexibility, allowing the use of various types of indoor units (with different capacities and configurations), individual zone control, and the unique ability to simultaneously provide heating and cooling in separate zones on a shared refrigerant circuit. They also allow heat recovery from one zone to another. Typical capacities range from 5.3 to 223 kW for outdoor units and from 1.5 to 35 kW for indoor units. VRF systems are equipped with at least one variable-speed compressor and/or variable-capacity compressor. Figure 1 illustrates the capacity control of a single variable-speed compressor; the compressor varies its speed to operate only at the levels necessary to maintain the indoor environments at the specified requirements.

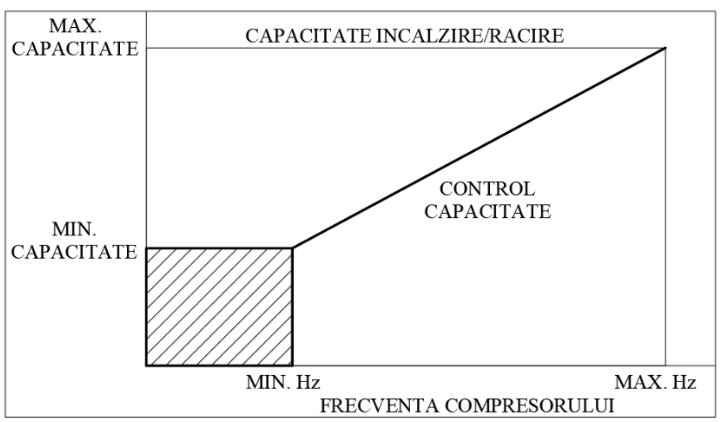

Fig. 1. Capacity control of a single variable-speed compressor

The studied system is a Variable Refrigerant Flow (VRF) configuration utilizing two pipes for both heating and cooling modes, combined with a heat recovery function to maximize energy efficiency.

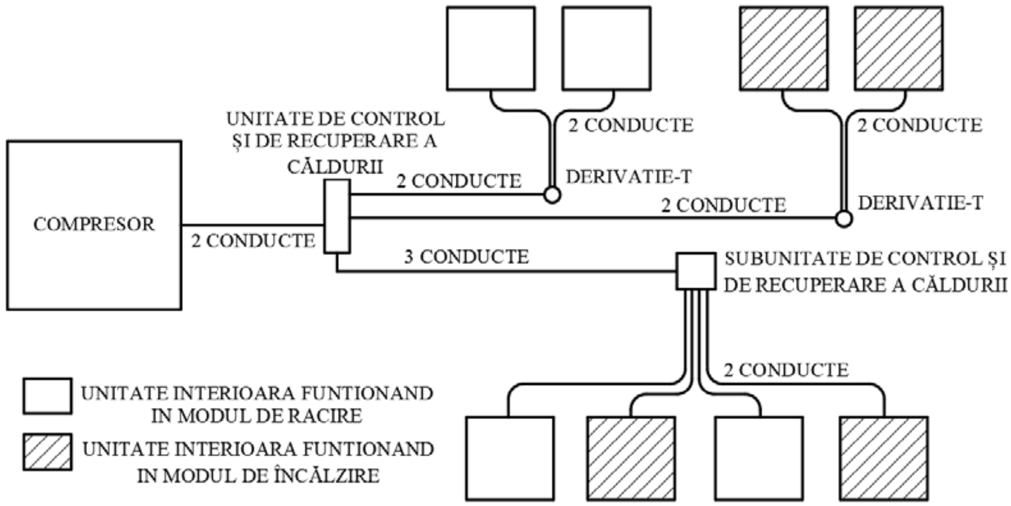

Fig. 2. VRF Systems in two pipes with heat recovery

VRF systems can be used in various applications, such as: office buildings, educational facilities (schools, universities), historic buildings, retail stores, production facilities (factories), cooling-only applications for data centers. VRF systems achieve individual temperature control for each zone, primarily by managing the refrigerant flow. Indoor units constantly react to changes in heating/cooling loads within each zone and maintain set conditions by controlling superheat through the use of an electronic expansion valve or a linear expansion valve. Inverter compressors, or a combination of inverter and constant-speed compressors, commonly found in VRF systems, modulate the refrigerant flow and work in synchronization with the refrigerant volume required by the indoor units. The major advantage of VRF air conditioning systems is energy efficiency. If the system operates at only 20% capacity, it does not consume energy as if it were running at 100% (unlike recirculation pumps that operate at full capacity), and the piping network where no indoor units are active has no energy consumption. In spaces with multiple rooms, a VRF system is much easier to manage because its electronic controls inherently know how to manage all indoor units. This also makes it very easy to implement a centralized control system for the VRF network, which, for example, allows all indoor units to be turned off from a single point.

3. Case study

This study addresses both the comparative analysis between a classic system (boiler – chiller – fan coil units) and a modern system (VRF – Variable refrigerant flow – indoor units) for heating and cooling, as well as the design approach and cost analysis for the construction of a Production hall – Sewing factory.
Building characteristics:
Importance category: “C”
Importance class: III (according to P100-1/2013)

Fire resistance rating: II
Height regime: Ground floor only (P)
External climate parameters:
Winter outdoor temperature: −18°C
Summer outdoor temperature: 35°C
Summer relative humidity: 35%
Winter relative humidity: 80% (seems duplicated; might need checking)
Indoor temperature targets:
25–27°C during the warm season for the production hall (sewing factory)

The cooling of indoor spaces, to maintain the temperature levels specified in standards (SR 6648-1,2), will be achieved through the following systems:
a) Chiller and fan coil units
b) VRF (Variable Refrigerant Flow) system with indoor units
Temperature regulation within the space will be performed using manual room thermostats. All equipment will be supplied through multilayer pipes with high resistance, certified for buried installation. The pipes will be insulated to prevent condensation and energy loss. Distribution will occur vertically through dedicated pipe shafts and horizontally through suspended ceilings. Pipes will be fixed to the building structure (where applicable) using single or double pipe clamps with rubber gaskets.
Number of people = number of workstations: 448 workstations
Specific heat released: 23 W/person (based on I5 standard, light work category)
From lighting: 20 W per m^2 in the production area
From other sources: 26.88 kW from sewing machines (300 W/sewing machine × 448 machines)
The distribution of the heating medium (hot water) will be made at the upper part, through the false ceiling in the main hallway.
The shortest routes from the distribution system to the fan coil units will be selected.
Supply pipes will use multilayer high-resistance pipes, certified for buried installation.
For straight pipe sections longer than 7 meters, expansion loops will be provided.
Following the calculations to determine the cooling requirement, a total of 96.34 kW was needed.

Description of HVAC Systems

a) Classic system:
Boiler with a power of 60 kW (running on liquid fuel/gas)
Chiller with a power of 100 kW
10 fan coil units (Heating capacity: 3 kW each, Cooling capacity: 10 kW each)

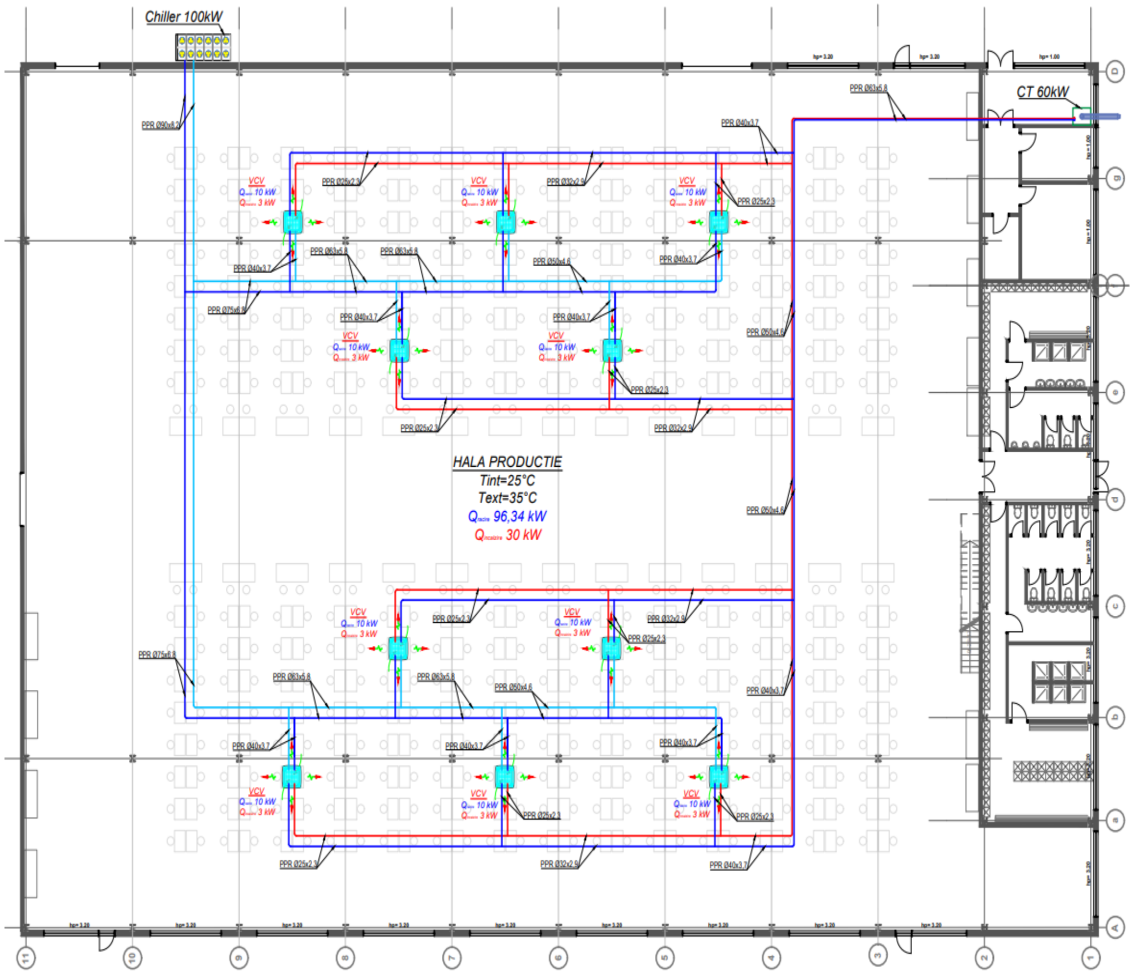

Fig. 3. Classic System

b) Modern system:
VRF (Variable Refrigerant Flow) system with one outdoor module
Cooling capacity: 100 kW
8 indoor units (5 units of 14.2 kW and 3 units of 11.2 kW)

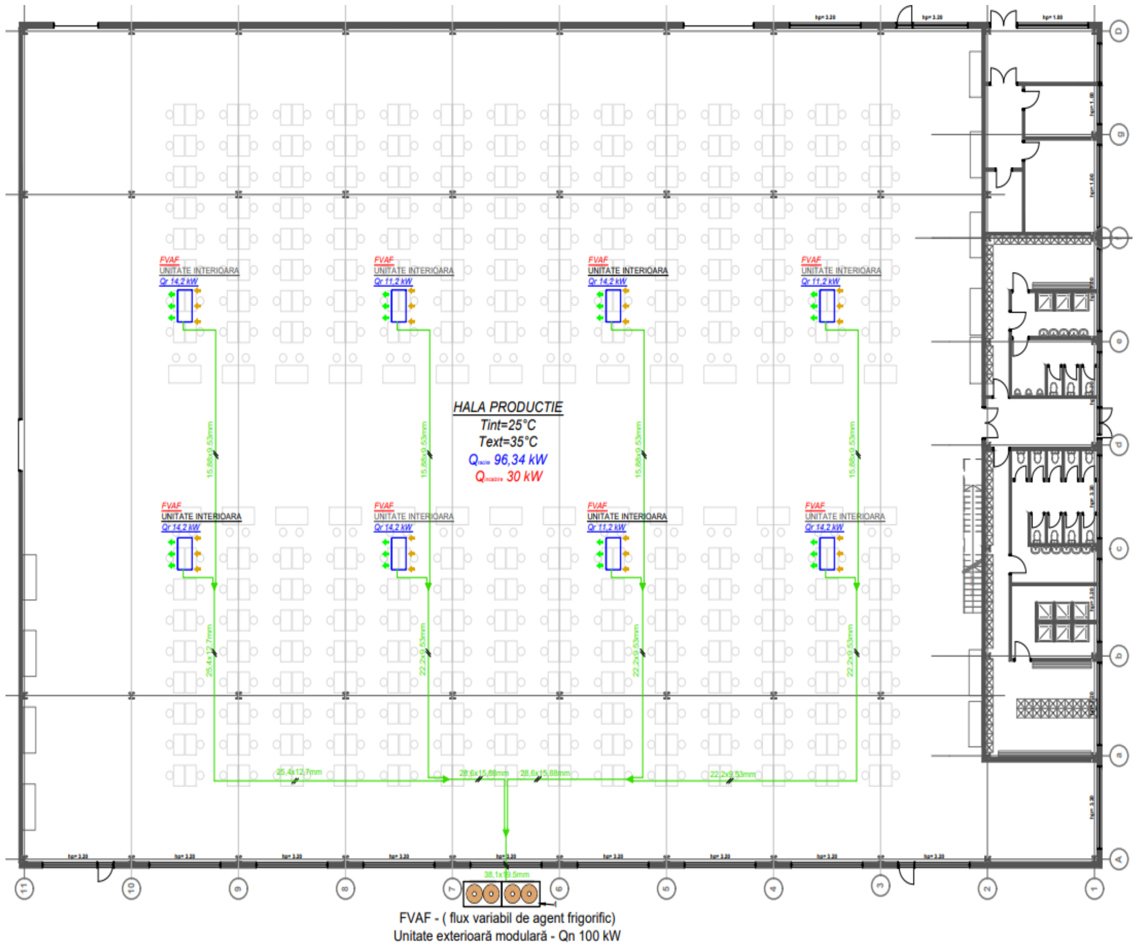

Fig. 4. Modern System

4. Conclusions

Following the study, the following conclusions were drawn:

- The VRF (Variable Refrigerant Flow) system offers greater long-term sustainability, as clients save on energy costs while simultaneously reducing carbon emissions by 35%.
- Higher energy efficiency - VRF systems use inverters and variable-speed compressors, adjusting the refrigerant flow based on actual needs, and are known for their enhanced energy efficiency.

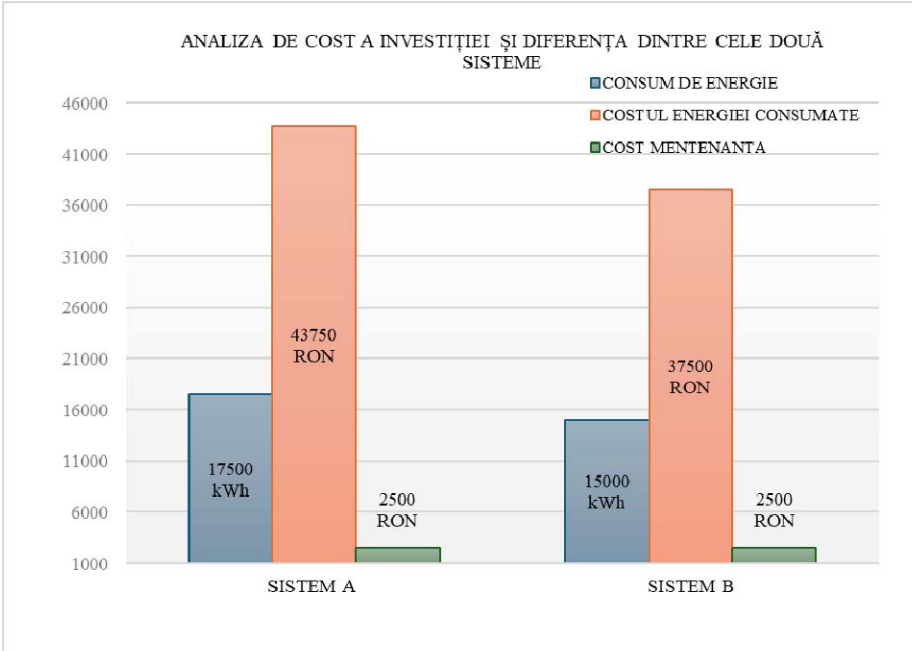

Fig. 5. Investment cost

The cost difference between the two systems (System A – traditional and System B – VRF) is 9.41%, with System B being more expensive at acquisition and commissioning.

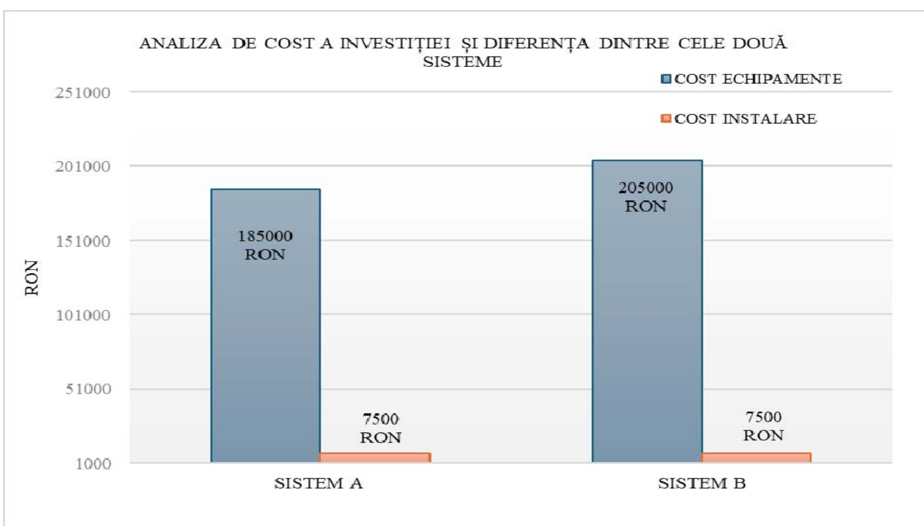

Fig. 6. Investment cost

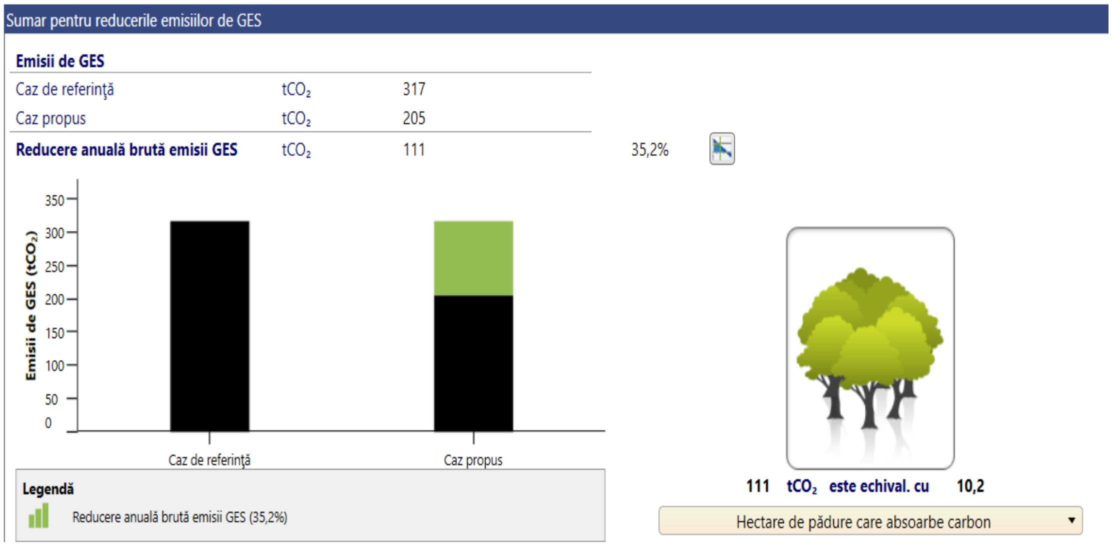

Fig. 7. Environment impact

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