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Replacing the existing thermo-frigo-pump (with pistons compressors) by a new thermo-frigo-pump with variable-speed screw resulted in a 50% saving of energy use!

José Naveteur^{1,*}

¹EDF R&D Technologies and Research for Energy Efficiency Department, 77250 Moret sur Loing et Orvanne, France

Abstract. Since 1998, EDF R & D provides energy monitoring of an office building (S = 16633m²) in Lyon and is heating and cooling by a thermo frigo pumps on groundwater. In 2014, it was decided to renovate the production of hot and cold and replace:

- The Existing thermo frigo pumps (with piston compressors) by new machines with variable speed compressors.
 - All the water pumps with new variable speed pumps
- The measures realized average 2015-2017(variable speed compressors), compare to average 1999-2013 (pistons compressors), have shown that
- The building consumption was reduced by 37%
 - The consumption of water pumps 47%
 - The consumption of thermo frigo pumps lowered by more than 50% and the COP heating + cooling (*) factor improved by 70%!.
 - The CO₂ emissions are also reduced by 50% compared to older the heat pumps. Compared to a gas boiler and chiller solution, the heat pumps with the new machines reduces the CO₂ emissions of 83%.
 - All of these improvements led to a reduction in CO₂ emissions of 37% (of the building).
- This is the only site in France that has measures (before and after replacement) and certainly the only site in Europe.

1 Introduction

Since 1998, EDF R & D realizes monitoring of energy use of an office building located in Lyon (area of 16 663m²), which includes offices (627), meeting rooms, and a conference room.

The peculiarity of this building is to be heated and cooled by a thermo-frigo-pump on groundwater that provides:

- The heating in winter
- The air conditioning of the computer room all year and offices, meeting rooms and amphitheatre in the summer.

The thermo-frigo-pump realizes the energy transfer between the hot and cold needs by the building which results in excellent performance of the installation, hot or cold surpluses are evacuated by the ground water. It is an ideal solution in terms of energy and costs for buildings which have both cooling and heating needs.

2 Technical site characteristics

In October 2013, the building owner decided to improve the energy performance of the building, this one, well maintained, does not justify energy renovation of facades. As regards the PACs, equipped with piston compressors, with over 130 000 hours of operation without major problems, it could be interesting to study their replacement (in advance) by new machines with latest generation screw compressors operating variable speed.

A study by the consultancy ARTELIA (Lyon agency) has highlighted the interest of upgrading the production of hot and cold by thermo-frigo-pump, namely PACs, pumps, regulation, and metrology.

The installation comprises two water/water heat pumps which feed a network of 4-pipe fan coils (630) and Air Handling (5) Units with energy recovery to limit energy use.

The hydraulic systems are fitted with variable speed pumps. The well comprises two variable speed-boring pumps with a maximum flow rate per unit of 100 m³/hr.

Groundwater is at a depth of 5m, drilling units (1 pumping and 1 injection) are at a depth of 20m, and they 316L stainless steel 800 mm diameter.

The two new heat pumps are with screw compressors operating variable speed manufactured by CARRIER type 30XWHV580 (Eurovent Certified), they replace two heat pump with piston compressors (CARRIER 30HG280).

The main characteristics of new heat pumps (data sheet of CARRIER)

Heating mode

- Heating capacity (45/50 °C) = 2 * 633.4 kW Hot
- Power consumption = 2 * 155.2 kW,
- COP in Heating mode= 4.08

Cooling mode

- Cooling capacity (7/12 °C) = 2 * 618.8kW Cold
- Power consumption = 2 * 96.2kW
- EER= 6.43, EESER = 7.80

Operating conditions:

-Chilled water is 7-12°C in summer and 10-12°C in winter.

-Hot water is 35°C when it is above 20°C outside and 45°C when it is 0°C outside. The whole installation is managed by a BMS (Building Management System).

Control

This is based on a fundamental principle: “always satisfy the highest demand.” The BMS must continuously measure the differences in temperature between the two systems (hot and cold). Depending on which system has a higher demand, it determines the operating conditions for the thermo-frigo-pump by prioritising hot or cold operation.

All of the installations are run by a Metaproductique-brand engineering management system.

How a thermo-frigo-pump works

A thermo frigo pump has five different modes, including:

Heating mode. This mode is used during cold spells. To achieve thermal equilibrium, all the cold produced by the units is discharged into the well.

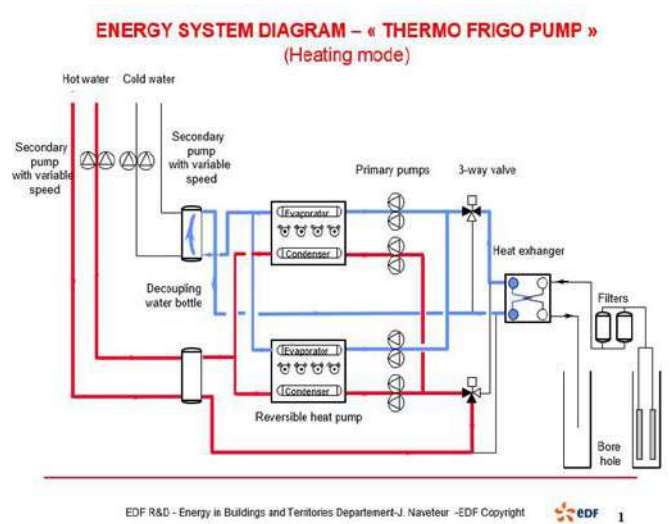


Fig 1: Thermo-frigo-pump in heating mode

Majority heat and minority cold. The building consumes more heat than cold (mid-season and start of winter). Surplus cold is discharged into the well.

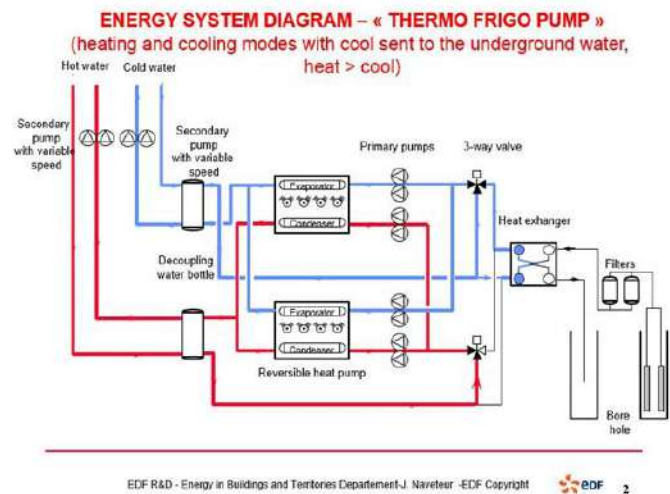


Fig 2: Thermo-frigo-pump with heat > cool

Heat equal to cold. This mode is used when the building consumes all the cold and heat produced. The COP is at its maximum and no energy is discharged into the well.

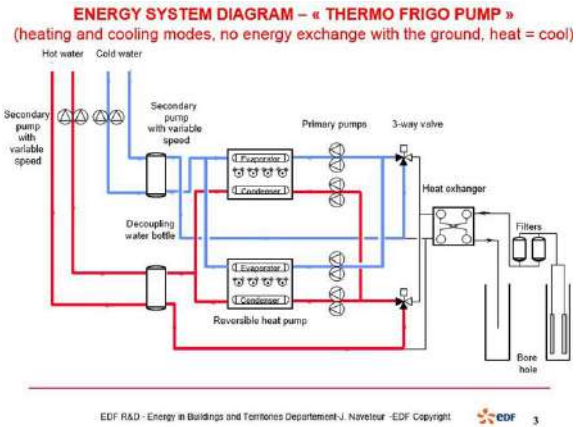


Fig 3: Thermo-frigo-pump with heat = cool

Majority cold and minority heat. The building consumes more cold than heat (mid-season and end of winter). Surplus heat is discharged into the well.

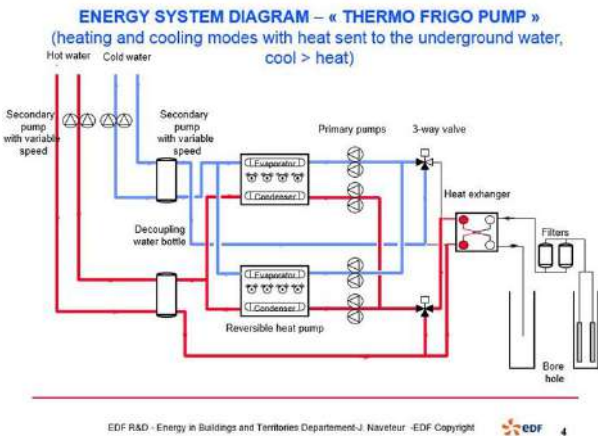


Fig 4: Thermo-frigo-pump with cool > heat

Cooling mode. This mode is used during summer. To achieve thermal equilibrium, all the heat produced by the units is discharged into the well.

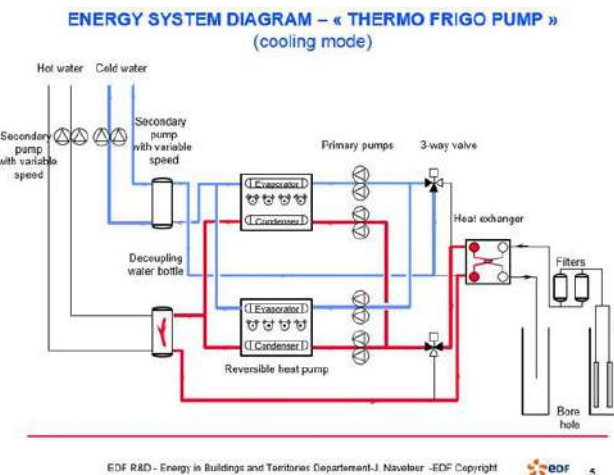


Fig 5: Thermo-frigo-pump cooling mode

3 Measurement results average 2015-2017 compare at average 1998-2013

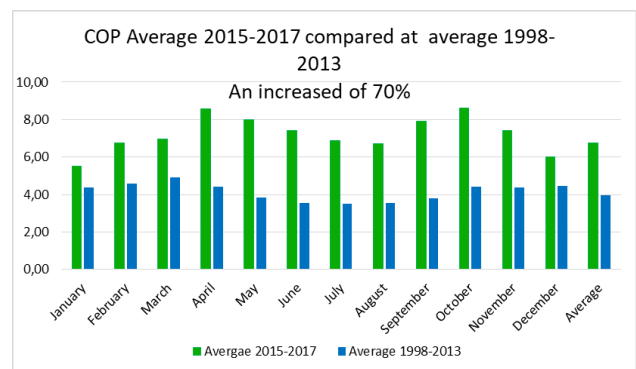
The site has been monitored for energy performance since 1998 with monitoring installation carried out by EDF R&D using 9 electricity meters (6 of which having remote reading capabilities), 1 heating meter, 1 cooling meter and 1 BMS remote investigation and monitoring system. This is the only site in France that has measures (before and after replacement) and certainly the only site in Europe.

The building energy use decreased by **37%**, and for the heat pumps by nearly **50%**. It should be noted that all energy uses are reduced which demonstrates the result of good operational management of the site.

Table 1. Average 1998-2013 compare with average 2015-2017 (EDF R&D).

Area 16 633m2	Average 1998 2013	Average 2015-2017 compared with the average 1998 to 2013	Average 2015-2017
Total consumption	157kWh/m ²	-37,18%	99kWh/m ²
Consumption of Heat pumps	37kWh/m ²	-50,02%	18kWh/m ²
Consumption of water Pumps	18kWh/m ²	-47,11%	10kWh/m ²
Consumption of Air Handling Units	12kWh/m ²	-30,23%	8kWh/m ²
Consumption of other uses	90kWh/m ²	-30,80%	62kWh/m ²
Heating Degree Days	2187	-4,15%	2096
kWh heating/Degree Days (DD)consumption by the building	515kWh/DD	-11,69%	455kWh/DD
Heating consumption	68kWh Heating/m ²	-15,47%	57kWh Heating/m ²
Cooling consumption	81kWh Cooling/m ²	-5,34%	77kWh Cooling/m ²

The COP in heating +cooling increased by 70%!



*COP = Hot and cold energy use by the building / Electrical energy consumed by the heat pumps + the drilling pumps.

-The cost of total energy use has decreased by **4.63 € HT^(Nb) /m²**, and by **1.49 € HT/m²** for the heat pumps and by **0.70 € HT / m²** for the all the pumps.

-The average cost of producing the MWh's of heating/cooling is **€13/MWh** and decreased by 42%

-The CO2 emissions are also reduced by **50%** compared to older the heat pumps. Compared to a gas boiler and chiller solution, the heat pumps with the new machines reduces the CO2 emissions of 83%.

- All of these improvements led to a reduction in CO2 emissions of 37% (of the building).

-The cost of renovation of the heat pump (Heat pumps, pumps, management system,) is 349k € HT or 25 € HT / m². **The payback time (IRR) is 11.5 years!**

^(Nb) HT indicates: All cost in this article exclude taxes

4 Know-how transfer

Given the experience gained during this monitoring, we then carried out other onsite monitoring at other buildings equipped with geothermal heat pumps such as a shopping center (1), a town hall (2), a museum (3), a swimming pool and an auditorium which is equipped with a heat pump pile foundations.

We have written many articles (4, 5) and conference contributions (6) reporting the results of these facilities and we participated in drafting technical guide (7).

We also work in courses organized by the National Agency for Energy Management and universities where we train interns and students to achieve this type of facility.

EDF R&D is recognized as one of the actors of this type of installation in France

5 Conclusion

This Replacing heat pump has resulted to:

-Reduced 50% of energy use.

-Reduced 50% of CO2 emissions.

-Reduce by 42% of the cost of MWh's of cold/heat production.

The time of return on investment of 11.5 years is considered satisfactory.

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Member (since 2003) of the drafting committee of the revue heating, ventilation and air conditioning. This is the revue of AICVF (French association of engineers in heating and air conditioning).

Member (since 2015) of Board of Directors of AICVF (French association of engineers in heating and air conditioning) - REHVA members