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Integrated district heating system for the San Cataldo area (Pisa, Italy)

by Marco Conti[1], Gastone Ghelardoni' & *Carlo Piemonte[2]

[1] AGES, via C. Battisti 71,56100 Pisa, Italy, agesadmin@ages.it

[2] Dipartimento di Energetica, Politecnico di Milano, p.za L. da Vinci **32, 20133** Milano, Italy, studioax@tin.it

ABSTRACT

Ages, which is the Company in charge for the natural gas distribution in the town of Pisa and surroundings municipalities, is interested in co-operating with Enel for the S.Cataldo project. Enel shall be responsible for the drilling of the production and reinjection geothermal wells and shall supply the thermal demand of a large research centre, belonging to CNR (National Research Council), by means of a direct utilization (heat exchanger) of the geothermal fluid wellhead.

The temperature of the geothermal fluid downstream the CNR plant is still high enough for a further utilization of the fluid itself and consequently Ages shall receive the fluid from Enel **for** feeding a district heating system with the geothermal heat, by means of large heat pumps. The system is completed with a cogeneration plant, which shall supply the electricity required for feeding the needs of the heat pumps and of the CNR research centre; the cogeneration plant shall integrate the heat extracted from the geothermal source and delivered to the distribution system and, in summer, will also give a contribution to the cooling load of the research centre by the utilization of absorption units.

KEYWORDS

District heating, heat pumps, cogeneration

1. Geothermal source

Large low enthalpy geothermal resources are available in the Pisa plain and have been well known for several years, but their exploitation is hampered by salinity and subsidence problems and by the difficulty of finding large thermal users to justify the investments in a particularly mild climatic area (BALDACCI et al. 1996).

The project presented in the paper represents one part of the first initiative for the development of the exploitation of these resources.

The geothermal well shall he drilled by Enel, in **the** area of a large research centre, belonging to ***CNR*** (National Research Council), and **Enel** itself is in charge for the utilization of the fluid for supplying the thermal demand of the ***CNR*** research centre, by means of a direct utilization (heat exchanger) of the geothermal fluid wellhead. **Enel** shall also take care of the reinjection well for the exploited fluid.

The studies carried out in the **area** revealed the possibility of finding a geothermal reservoir at a depth of 400 m from ground level, with a wellhead temperature of ***70°C.***The available flow is expected to be 200 t/h.

As above reported, this fluid shall be first of all exploited for supplying the ***CNR*** thermal users, by means of direct heat exchangers, which will release the fluid at an estimated temperature of 58°C, in correspondence with the peak load conditions of the ***CNR*** plants.

Ages has developed a project for feeding a district heating system by exploiting the remaining thermal content of this fluid, with a maximum temperature of ***58°C*** and a flow of ***200*** t/h. The temperature shall vary during the heating season, depending upon the variation of the operating temperatures in the ***CNR*** plants. The range of variation of the temperature **of** the fluid delivered by ***CNR*** to Ages is expected to he 50-62°C.

2. Energy demand to be covered by the integrated system

The integrated plant, which is described in detail under chapter **3,** is a total energy system which will produce electrical energy, thermal energy and cooling energy.

The electrical production of the plant will cover the electrical demand of ***CNR*** (near 9,000 MWh/year) and the electrical consumption of the district heating system **(near** 4,000 MWh/year, including two electrically driven heat pumps).

The district heating system will supply a basin of users in the surroundings of the ***CNR*** centre, with an overall volume near to 1,000,000 cubic meters. The thermal users investigation estimated a peak power of ***25*** MW and a thermal demand near to ***35,000***MWh/year.

The cooling energy produced by the plant will he supplied completely to the CNR users, which are presently fed by electrically driven compression chillers, with an overall power of ***7,000***kW_f.

3. Description of the energy production station

3.1 Basic sections

The system is fed by a total energy station, which includes three basic sections:

- cogeneration (with two reciprocating engines);
- thermal station with geothermal energy exploitation (with two heat pumps, primary heat exchangers and peak load boilers);
- cooling station (with two absorption cooling groups).

3.2 Cogeneration

The cogeneration system will be based upon two gas fed reciprocating engines, with Otto cycle.

For each engine, the thermal energy recovery is arranged in two sections:

- the heat recovered from the cooling circuit of the engines is supplied to a hot water circuit;
- the heat recovered from the exhaust gases of the engines is used for producing saturated steam at 8 bar g.

The two engines are identical and the nominal data of each of them are the following:

- electrical power: 1,457 kW
- thermal power recovered by:
  - hot water circuit: 796 kW
  - steam circuit: 720 kW
  - total: 1,516 kW
- primary energy consumption: 3,676 kW

During the summer, the thermal energy supplied to the steam circuit is utilized for feeding the absorption cooling groups mentioned under 3.1., whereas no utilization is provided for the heat available by the hot water circuit.

In winter the steam is sent to a beat exchanger and transfers energy to the hot water circuit. This circuit is connected to the district heating system and therefore the whole heat available in cogeneration is utilized in that plant.

3.3 Geothermal district heating system

The exploitation of the geothermal fluid is based upon a HPA (Heat-Pump Assisted) scheme, which feeds a district beating network, operating with design temperatures of 90°C (supply) and 60°C (return). The figure 1 shows the flowscheme of the whole system, together with thermal balance in peak load conditions, in winter.

Part of the flow of the water coming from the return of the district heating network is sent to the evaporator of two series-connected heat pumps and is cooled down to 27°C. Then, the water is sent to a primary heat exchanger, fed by the geothermal fluid at 58°C, and is heated up to 55°C.

The branch including the a.m. items is arranged in parallel with a by-pass for the remaining part of the district heating water. The mixture between the return water (at 60°C) and the water at 55°C gives an average temperature of 58°C.

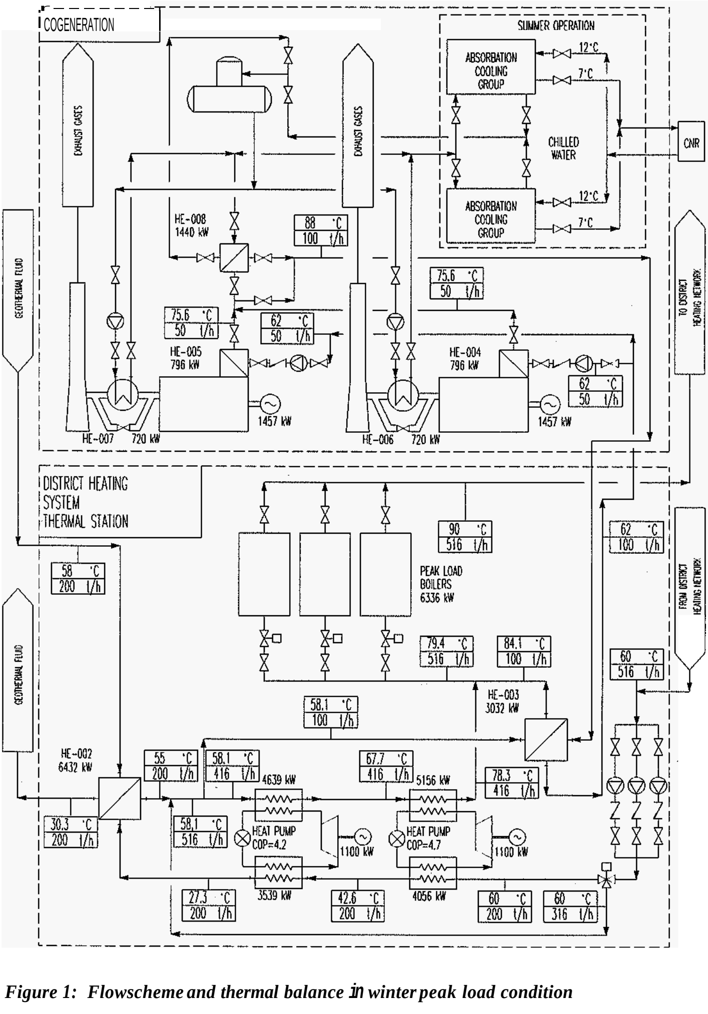

Figure 1: Flowscheme and thermal balance in winter peak load condition

Figure 1 is a simplified scheme and shows only one primary heat exchanger; really, the plant shall include two primary heat exchangers in parallel, each of them dimensioned for the peak power, thus allowing the possibility of continuing the operation, even when one of them is put in maintenance for cleaning the interiors, as geothermal fluids are normally expected to cause a certain degree of scaling (HARRISON et al. 1990, PIEMONTE et al. 1991).

Downstream the primary heat exchanger, the water flow rate is again divided in two streams: one is sent to the series-connected condensers of the two heat pumps and is heated up to 78°C, whereas the other one is sent to a heat exchanger fed by the hot water circuit of the cogeneration system and reaches the temperature of 84°C. The mixture of the two flows has an average temperature near to 80°C.

The final step, in the thermal station, is represented by peak load boilers, which allow the water to reach the supply temperature of 90°C.

The district heating system has a peak load power of 18 MW. In the above described configuration, the contribution of each thermal unit is the following:

- cooling power subtracted by evaporators: -7,600 kW
- thermal power supplied by:
  - primary heat exchanger: 6,400 kW
  - heat pump condensers: 9,800 kW
  - cogeneration: 3,000 kW
  - peak load boilers: 6,400 kW

On a whole, the base-load units will cover by 64% of the peak power and the boilers the remaining 36%.

3.4 Cooling station

The cooling station is based upon an absorption cooling group, fed by the 8 bar steam produced in cogeneration. The nominal COP of this group is 1,15 and the maximum cooling power is 1,650 kW, with a thermal consumption of 1,435 kW.

4. Energy balance

4.1 Simulation of the system operation

A simulation of the system operation for a whole year has been carried out, by means of a dedicated software, taking into account the differences between summer and winter operation and considering several load conditions for both seasons (PIATTI et al. 1992).

Table 1 reports the summary of the energy calculations, with the figures relevant to both seasons and the year total.

Table 1: Energy balance of the total energy system, through one year of operation

ENERGY (MWh/year)	winter	summer	total
Electrical energy production	8,141	4,960	13,101
• CNR's geothermal plant			
• CNR's other users	318	[illegible]	[illegible]
• district heating system	[illegible]	754	[illegible]
• total	[illegible]	4,960	[illegible]
Cooling energy	8,141	[illegible]	[illegible]
Thermal energy fed to the district heating system		939	939
• fed to users	26,571		26,571
• losses in the distribution network	2,483		2,483
• total	29,054		29,054
Thermal energy produced by:			
• heat pump evaporator n. 2	-6,237		-6,237
• heat pump evaporator n. 1	-5,975		-5,975
• heat exchanger HE-002	15,809		15,809
• heat pump condenser n. 1	7,430		7,430
• heat pump condenser n. 2	7,691		7,691
• cogeneration	8,491		8,491
• **peak load boilers**	1,845		1,845
• total	29,055		29,055
Thermal energy cogenerated			
• **hot water circuit**	4,450		4,450
• **steam circuit**	4,041	1,686	5,727
• **total**	8,491	1,686	10,177

The total energy systems will produce the following figures:

- electrical energy: 13,100 MWh/year
- thermal energy: 29,000 MWh/year
- cooling energy: 1,900 MWh/year
- TOTAL 44,000 MWh/year

The thermal energy production is covered by 94% by the base-load units, whereas the boilers will cover only the 6% of the total thermal demand.

The primary energy consumption of the whole system (meaning the two cogeneration engines and the peak load boilers) is 35,500 MWh/year and the geothermal fluid makes available near 16,000 MWh/year.

It is worth mentioning that, due to the geothermal contribution, the overall energy made available for the users is much higher than the primary energy consumption.

4.2 Energy saving

The present primary energy consumption, for producing the electrical, thermal and cooling energy made available by the whole system (as reported under 4.1.) has been calculated in 60,500 MWh/year and therefore the energy saving obtainable by means of the plant is near 25,000 MWh/year, which represents the 40% of the present consumption.

5. Economics

The investment for the total energy plant described in this paper has been evaluated in 25,000 million ITL, equivalent to 12,900,000 Euro.

The yearly profit, calculated by means of the simulation of the system operation, will be 2,450 millions ITL/year (1,265,000 Euro/year), thus allowing a discounted pay-hack period (calculated according to a discount rate by 5%) lower than years of operation and an internal rate of return higher than 7% (PIATTI 1991).

6. Status of the project

The drilling of the production geothermal well is at present under way. The results of the drilling activity are expected in the late summer 1999.

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