The heat storage in district heating systems: from environmental and cost savings to higher flexibility of CHP plants – The Turin DH system

The hydroelectric pumping system: IREN experience

October 22nd, 2014
Summary

1. IREN Group energy activities
2. Thermal energy storage in Turin district heating system
3. Pont Ventoux-Susa and Valsoera-Telessio hydro pumping systems
IREN Group
IREN Group

IREN, a multiutility company listed on the Italian Stock Exchange, operates in the sectors of:

- **electricity** (production, distribution and sale)
- thermal energy for **district heating** (production and sale)
- **gas** (distribution and sale)
- the management of **integrated water services**
- **environmental services** (collection and disposal of waste)
- **services for the local authorities.**
Cogenerative, thermal and thermoelectric production

1\textsuperscript{st} operator in Italy in District Heating

83\% of Heat co-generated

Up to 90\% Efficiency in CHP

Over 2,700 MW of electric capacity

Over 2,300 MWt of thermal capacity

Moncalieri 800 MW CCGT & CHP Plant

Turbigo 800MW CCGT Plant

Torino Nord 400 MW CCGT Plant

Politecnico HOB Plant
Turin DH integrated system

CHP = Combined Heat and Power
HOB = Heat-Only Boiler
= Heat Accumulators

2013 IREN Heat production (GWh)

Heat from HOB: 17%
Heat from CHP: 83%

TORINO NORD (CHP+HOB)
MARTINETTO
POLITECNICO (HOB)
MIRAFIORI NORD (HOB)
BIT (HOB)
MONCALIERI (CHP+HOB)
IREN Group has a strong experience in electricity and heat generation that started in 1907 and has grown through several green and brown fields projects till nowadays.

**Orco Valley (Iren Energia)**
- 6 hydroelectric plants (296MW, production 750 GWh/y)

**Susa Valley and Turin (Iren Energia)**
- 3 hydroelectric plants (168 MW, production 400 GWh/y)

**Brugneto and Canate (CAE)**
- 2 hydroelectric plants (10 MW, production 45 GWh/y)

**Baiso (Iren Ambiente)**
- 1 hydroelectric plant (1 MW, production 8 GWh/y)

**Tusciano plants (Iren Energia)**
- 7 hydroelectric plants (110 MW, production 250 GWh/y)

**Turbigo power plant (Iren Energia)**
- 1 CCGT unit (800 MWe)

**TURIN heat & power center (Iren Energia)**
- 3 main CHP CCGT units (1,200 MWe and 760 MWt)
- integration and back-up boilers (991 MWt)
- heat storage units (12,500 m³)

**Reggio Emilia, Parma and Piacenza plants (Iren Energia)**
- 1 CCGTCHP plant (63 MWe 54 MWt)
- 1 gas open cycle (19 MW)
- integration and back-up boilers (330 MWt)

**Sampierdarena plant (Iren Energia)**
- 1 gas CHP plant (29 MWe 30 MWt)
- integration and back-up boilers (38 MWt)

**Total:**
- Thermoelectric CHP: 1,300 MW
- Thermoelectric (CCGT): 800 MW
- Hydroelectric: 600 MW
- Total: 2,700 MW
2 Thermal Energy Storage
Italian electricity market since 2009 suffered from decline of demand (also thanks to strong investment in energy efficiency).

On the supply side, operators strongly invested both in renewable energy (thanks to public incentives) and in gas thermoelectric plants.

**Italian electric demand**

![Graph showing Italian electricity demand and installed capacity from 2005 to 2013.](image)

- **Thermoelectric production**
- **Net import**
- **Other renewable**
- **CCGT installed capacity**
- **RES installed capacity (no hydro)**

Impressive growth of both renewable and CCGT capacity combined with a decrease of demand.
Italian (and Euro-continental) electricity market are squeezing margins of CCGTs plants that are running 1000/2000 hours per year if non cogenerative

The great part of the main margin, but far below full operating cost recovery, comes from ancillary services to the TSO (Transmission System Operator).

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Spark Spread 2015 (PUN - GAS CCGT) - Euro/MWh

1 year ago expected Spark Spread for 2015

2015 Spark Spread (Forward Prices)

Current expected Spark Spread for 2015
Italian electricity market squeeze generation margins

In such market contest, CCGT plants that serve in CHP mode district heating networks have to carefully program electricity and heat production in order to meet respectively peak prices and heat demand.
Electricity market "needs" Vs heat demand "needs"

When the DH is supplied by thermoelectric plants the electric variable margin is added to the heat margin but...

...the two markets may diverge strongly in terms of time distribution of peak/offpeak demand.
Electricity market "needs" Vs heat demand "needs"

If heat demand is **LOW** and electricity price is **HIGH** (*):

- **Production in full electric mode**
  - Efficiency limited to 55%

- **Production in CHP mode with thermal storage**
  - Match with heat demand and total Efficiency rises up to 85-90%

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(*) If heat demand is **LOW** and electricity price is **LOW**, if extra margins coming from heat sales do not help covering variable costs of production, HOB must be used.
Electricity market "needs" Vs heat demand "needs"

<table>
<thead>
<tr>
<th>Electricity Generation Profit (€MWh)</th>
<th>Electricity Generation Loss</th>
</tr>
</thead>
</table>

- Turn off the plant - or minimize electricity production - and use heat accumulated in thermal storage when heat demand was low (night time)

If heat demand is **HIGH** and electricity price is **LOW** (*)

- Production in full CHP mode
  - Match with heat demand but heat sale profit reduced by electric loss
- Turn off the plant - or minimize electricity production - and use heat accumulated in thermal storage when heat demand was low (night time)
  - Full heat sale profit

(*) If heat demand is **HIGH** and electricity price is **HIGH**, production in CHP mode maximizes margins thanks to the total higher efficiency
Main benefit of Thermal Energy Storage in DH system

A Thermal Energy Storage integrated in a district heating network can bring the following benefits:

- full recovery of heat produced;
- maximization of efficiency of the system;
- reduction of heat generation installed capacity to cope with heat peak demand;
- increase of flexibility of CHP plant for electricity dispatching;
- short term recovery;
- rapid start up;
- highly flexible control of the heat flows;
- increase of the heated volumes by the installation of “local” heat storage systems in border zones (with hydraulic limits);
- maximization of the reliability (charging with the natural circulation of water and discharging with pumps);
- low operating and maintenance costs.
Heat storage system in Turin DH

The District Heating grid operate with superheated water at a delivery temperature normally between 105°C and 120°C, with the possibility of reaching a maximum temperature of 135°C in the winter and a minimum of 85°C in the summer.

The DH is based on a typical interconnected grid at the transport level and a radial grid at the distribution level.

The essential function of the accumulation system is the storage of the thermal energy produced by the cogenerators overnight, when the demand for heat is lower and its use during the hours of maximum load of the district heating system, reducing the use of the integration boilers to a minimum.

The Heat Accumulators systems are operated by remote control rooms.

Based on the service needs, the accumulation tanks may be filled and emptied several times a day.
Heat storage system in Turin DH

The typical system is made up of six pressurised tanks with the following characteristics:

- design pressure: 18 bars;
- design temperature: 210°C;
- corrosion allowance: 1 mm;
- outside diameter of plating: 7,000 mm;
- height of plating: 18,500 mm;
- internal radius of hemispherical bottoms: 3,500 mm;
- capacity: above 840 m³;
- height above ground 26 m.

Inside each accumulation tank, a water distribution system is active in both directions, to ensure a maximum capacity of 185 kg/s, so as to prevent the risk of remixing.

All the elements inside the tanks (pipes and distribution system) are made of stainless steel.
Heat storage system in Turin DH

The pumping station is made up of a set of 8 identical pumps in parallel with variable speeds obtained by varying the power supply frequency of the electric motors.

The pumps of the Pumping Station have the following characteristics (depending on the altitude of the installation site):

• nominal capacity: from 340 to 700 kg/s;
• head at nominal capacity: from 7.5 to 8.5 bars;
• N.P.S.H. required at nominal capacity at 20°C: from 5 to 6 m;
• capacity regulation range with frequency converter: 30%÷100%.
Heat storage system in Turin DH - Charging configuration

Heat Accumulators

Heat generators
Heat storage system in Turin DH - Discharging configuration

Heat Accumulators

Heat generators
### Turin DH System Main Figures

#### GRID MAIN FEATURES

<table>
<thead>
<tr>
<th></th>
<th>HEATED VOLUME</th>
<th>INHABITANTS</th>
<th>THERMAL PEAK</th>
<th>HEAT</th>
<th>PIPING</th>
<th>BUILDINGS</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mm³</td>
<td>num</td>
<td>MW</td>
<td>GWh/y</td>
<td>km</td>
<td>or UNITS</td>
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<tr>
<td>TORINO SUD-CENTRO</td>
<td>39</td>
<td>390,000</td>
<td>960</td>
<td>1.705</td>
<td>345</td>
<td>3,050</td>
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<tr>
<td>NICHELINO</td>
<td>1</td>
<td>10,000</td>
<td>50</td>
<td>80</td>
<td>20</td>
<td>400</td>
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<td>TORINO NORD</td>
<td>15</td>
<td>150,000</td>
<td>375</td>
<td>620</td>
<td>150</td>
<td>1,550</td>
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<tr>
<td>TOTAL</td>
<td>55</td>
<td>550,000</td>
<td>1,385</td>
<td>2,405</td>
<td>515</td>
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#### HEAT PRODUCTION AND STORAGE

<table>
<thead>
<tr>
<th></th>
<th>CHP</th>
<th>OHB</th>
<th>STORAGE</th>
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<tr>
<td>MONCALIERI</td>
<td>520 MWt</td>
<td>140 MWt</td>
<td>-</td>
</tr>
<tr>
<td>BIT</td>
<td>-</td>
<td>255 MWt</td>
<td>-</td>
</tr>
<tr>
<td>POLITECNICO</td>
<td>-</td>
<td>255 MWt</td>
<td>2,500 m³</td>
</tr>
<tr>
<td>MIRAFIORI NORD</td>
<td>-</td>
<td>35 MWt</td>
<td>-</td>
</tr>
<tr>
<td>TORINO NORD</td>
<td>240 MWt</td>
<td>340 MWt</td>
<td>5,000 m³</td>
</tr>
<tr>
<td>MARTINETTO (from oct-13)</td>
<td>-</td>
<td>-</td>
<td>5,000 m³</td>
</tr>
<tr>
<td>TOTAL</td>
<td>760 MWt</td>
<td>1,025 MWt</td>
<td>12,500 m³</td>
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</table>
Coverage of district heating Load with CCGT, HOB and Heat Accumulators

THERMAL SEASON 2013/2014 (Oct15th-Apr15th)

- **26 GWh**
  - **BOILERS**
  - **1.4 %**

- **-178 GWh**
  - **ACCUMULATORS CHARGE**

- **175 GWh**
  - **ACCUMULATORS DISCHARGE**

- **1.834 GWh**
  - **COGENERATION**
  - **98.6 %**

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100 %
Coverage of district heating Load with CCGT and Accumulators today in Turin

2013 December 31th  DH thermal diagram

- CCGT 1: Baseload
- CCGT 2: Mid-merit
- CCGT 3: Mid-merit
- Heat release from accumulators
- Heat storage in accumulators

COGENERATION
BOILERS
ACCUMULATORS DISCHARGE
ACCUMULATORS CHARGE
... and how it was before latest installation of 5,000 m³ of accumulators
3 Hydro Pumping
Pont Ventoux Hydro asset brief description

The hydroelectric system of Pont Ventoux is located in the North West of Italy, close to Turin. It has a daily capacity of reserve pumping.

- The diverted water flow runs about 14 km to the reservoir of Clarea Valley (561,000 m³ capacity).
- The intake facilities are situated at Pont Ventoux in the Oulx area on the river Dora Riparia (1,046m asl).
- An upstream dam, forming a small reservoir of 40,000 m³, allows a max flow rate of 33 m³/s.
- A pressured tunnel (4.3km) link the Clarea reservoir to the surge chamber, from which start the subsurface penstock (1.3km, max net head 503m).
- Downstream, a pressured tunnel (1.6km) returns the diverted water to the Gorge reservoir (capacity of 420,000 m³).
Pont Ventoux Hydro asset brief description

- Entry into operation (year): 2004
- Plant description: pump-storage
- Incentive: GC until 2019
- End of concession (year): 2034
- Installed Capacity: 150 MW (2 units: 75 MW – 17 m³/s)
- Installed Pump: 78 MW (unit n.2 – 13 m³/s)
- Energy produced 2013: 320,126 MWh

The reservoir of Clarea Valley (561,000 m³ capacity).

The Gorge Susa reservoir (capacity of 420,000 m³).
Valle Orco Hydro assets brief description

The hydroelectric system of Valle Orco is located in the North West of Italy, close to Turin. It consists of seven plants and of six artificial reservoirs for a total installed capacity of 296MW, mostly built between 1930 and 1970 and repowered between 2000 and 2010.

<table>
<thead>
<tr>
<th>Valle Orco</th>
<th>Start operation</th>
<th>Type of Power Plant</th>
<th>Repowering</th>
<th>Power Installed</th>
<th>2013 Energy produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Plants</td>
<td>year</td>
<td>description</td>
<td>year</td>
<td>MW</td>
<td>MWh</td>
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<tr>
<td>Agnel-Serrù-Villa</td>
<td>1962</td>
<td>storage</td>
<td>2005-2006</td>
<td>40</td>
<td>91,521</td>
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<tr>
<td>Ceresole-Rosone</td>
<td>1929</td>
<td>storage</td>
<td>2008-2010</td>
<td>99</td>
<td>531,195</td>
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<tr>
<td>Telessio-Eugio-Rosone</td>
<td>1956</td>
<td>storage</td>
<td>2008-2010</td>
<td>82</td>
<td></td>
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<tr>
<td>Rosone-Bardonetto</td>
<td>1941</td>
<td>run of river</td>
<td>2007-2008</td>
<td>18</td>
<td>86,128</td>
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<tr>
<td>Bardonetto-Pont</td>
<td>1945</td>
<td>run of river</td>
<td>2000-2004</td>
<td>15</td>
<td>75,456</td>
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<tr>
<td>Valsoera-Telessio</td>
<td>1970</td>
<td>pump storage</td>
<td>2010-2011</td>
<td>38 (34 pump)</td>
<td>42,101</td>
</tr>
<tr>
<td>San Lorenzo-Rosone</td>
<td>1999</td>
<td>run of river</td>
<td>-</td>
<td>4</td>
<td>8,666</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>296</td>
<td>835,067</td>
</tr>
</tbody>
</table>

All the repowered hydroelectric power plants have benefits of the governative incentive Green Certificates.
Valsoera - Telessio Hydro pumping system

This pump-storage plant with seasonal regulation reservoirs uses the water from the torrents Piantonetto, Valsoera and Balma stored in the Valsoera reservoir situated at 2,412 m a.s.l. and capable of containing 7.7 million m³ of water.

The Telessio power plant is in a cavern houses and it has a maximum net head of 555 m. The unit is a ternary horizontal type with an installed capacity of 38 MW in generation mode and 34 MW in pumping mode and a power output of about 40 GWh/year (of which 13 GWh/year from natural runoff and the rest from pumping).

Downstream of the plant, the water is returned to the Telessio reservoir from which it can be pumped back into the Valsoera reservoir so that it can be used to produce energy during the daytime when the prices is higher.

The Telessio reservoir is a seasonal regulation one, situated at 1,917 m a.s.l. and capable of containing 23 million m³.
The pumping system is profitable if the spread between peak prices and off-peak prices is above 25-30%.

In Italy in the day-ahead market such spread has been reducing dramatically from 100% before 2008 to less than 20%.
Italian Peak Vs Off-Peak Prices

The average premium is in 2014 below 10 €/MWh, and has been below 6 €/MWh during summer when solar photovoltaic plants hit the peak of production.

Premium Peak Vs Off-Peak (€/MWh)
Valsoera - Telessio water pumping for system balance

Since 2013 the Valsoera - Telessio pumping system is requested from the Transmission System Operator for ancillary services.

When the TSO, under specific condition, needs to balance the network load with power generation, it asks IREN to switch on the pumping mode in order to absorb electricity.
Thanks