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Small-scale Hydro within a Municipal Water Supply System

Summary

The city of Boulder, Colorado, has installed five small hydroelectric units within its municipal water supply system. Together, these units produce enough electricity to provide 7% of the electricity consumption of Boulder's 125,000 residents. Two more installations under construction will almost treble the city's hydro capacity. Electricity sales have helped to pay for improvements in local water quality. The project demonstrates how small hydroelectric equipment can be applied cost-effectively in municipal water supply systems, wherever a pressure-relief valve is used to reduce excess pressure in the supply lines.

Highlights

- **Small-scale hydro supplies 7% of a city's electricity**
- **Low environmental impact because existing water supply infrastructure is used**
- **Hydro units installed where pressure is released from water lines**
- **Income from electricity sales reduces local water rates**

Silver Lake Hydro Station, Colorado.

Project Background

In 1982, responding to popular opinion, Boulder decided to increase its use of renewable, non-polluting electricity. The city chose to develop small-scale hydro, not only because it was the most cost-effective renewable energy technology available at the time, but also because there was unused energy potential in the city's municipal water supply system.

By 1987, Boulder had installed five small-scale hydroelectric power stations on its municipal water system, with a combined rated capacity of 4.1 MW. Two more stations are currently under construction, scheduled to go on-line by 2001, adding another 7 MW of capacity to the system.

The power stations take advantage of excess pressure in the city's water supply, which flows from the North Boulder Creek watershed near the continental divide of the Rocky Mountains, at an altitude of 3,015 m above sea level. Boulder is situated in the foothills, at an altitude of 1,630 m, and the excess pressure was previously vented to the atmosphere through relief valves located at various points along the line, including at the entrance to the water treatment plant.

The Project

The project involved installing turbine generators at points where pressure-relief valves were operating, using the excess pressure in the flowing water to generate electric power.

Each hydroelectric station uses equipment tailored to its location. Where valves release some of the pressure in the pipelines, such as along treated-water lines before delivery to customers, reaction-type Francis turbines have been installed to keep some pressure in the line at the outlet. Elsewhere in the system, such as at the water treatment plant where pipelines discharge into reservoirs at atmospheric pressure, impulse-type Pelton turbines are used.

At sites of lesser potential, usually along treated-water supply lines, low-cost induction generators of between 70 and 800 kW were installed. In two locations, these generators can also operate in reverse, as pumps for use in emergencies. On larger pipelines, slightly more expensive synchronous generators are used to supply electricity to the utility at the higher efficiency required.

Performance

Between 1990 and 1998, Boulder's hydroelectric stations produced an average of 15.1 GWh/year. The stations operate automatically and are controlled remotely from the water treatment plant. The city employs two full-time staff for daily maintenance and hires private firms periodically to overhaul the components.

Boulder's hydropower plants are extremely reliable and efficient, operating for 96% of the time or 50 weeks a year, on average. Using standard "off-the-shelf" equipment,

Table 1: Boulder's hydroelectric facilities

Name of hydro station	Rated capacity (kW)	Type of turbine	Type of generator	Water source	In-service date	Annual generation (kWh)	Annual revenue (US $)	Construction cost (US $)
Maxwell	70	Reaction	Induction	Treated	Mar. 1985	513,382	20,573	110,000 [1]
Kohler	136	Reaction	Induction	Treated	Nov. 1985	598,889	32,903	280,000 [2]
Orodell	180	Reaction	Induction	Treated	Sep. 1987	823,022	19,507	540,000
Sunshine	800	Reaction	Induction	Treated	Sep. 1987	4,151,523	177,833	1,100,000
Betasso	2,900	Impulse	Synchronous	Raw	Dec. 1987	9,056,116	539,419	3,200,000
Silver Lake	3,500	Impulse	Synchronous	Raw	May 2000	17,000,000*	500,000*	4,426,503*
Lakewood	3,500	Impulse	Synchronous	Raw	Late 2001	19,621,000*	800,000*	2,174,000*

* Estimated.
[1] Hydroelectric portion; the total cost of the Maxwell Pump Generation station was $300,000.
[2] Hydroelectric portion only; the total cost of the Kohler Pump Generation Station was $526,000.

they convert up to 85% of the potential energy in the water line to electricity, which is then delivered to customers.

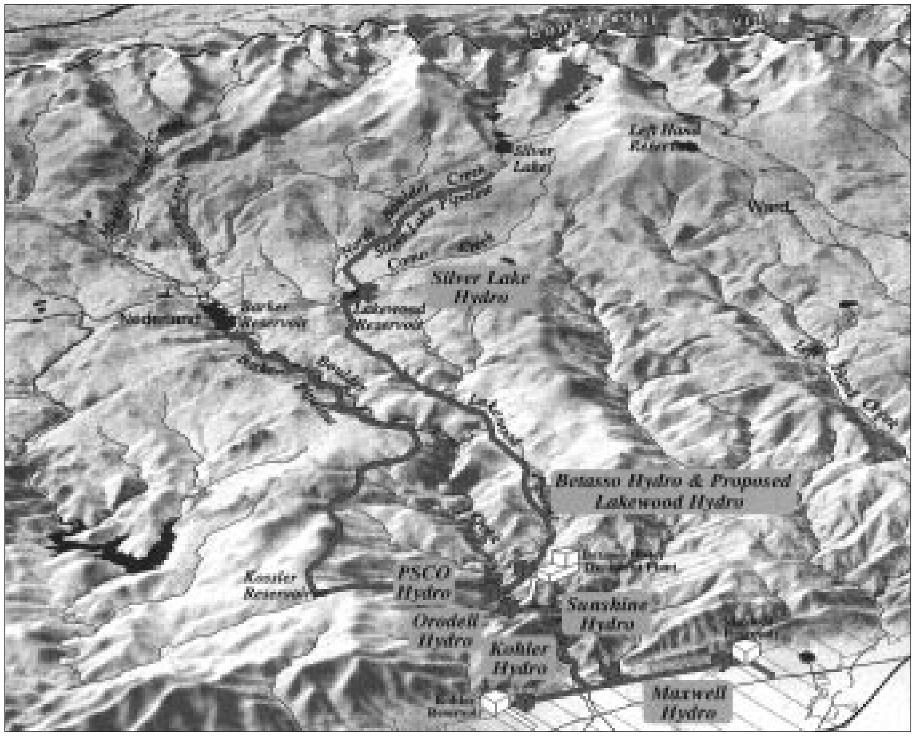
Economics

Boulder receives an average of $790,000/year from the local electricity company for its hydroelectricity, representing an average $0.05/kWh (where $ is the US dollar). This includes capacity payments, which account for two-thirds of the revenue.

The total installed cost of the five operating hydro plants was $5.2 million, at an average cost of $1,280/kW. The simple payback period on the investment, including interest payments, is 10–15 years.

The cost of connection to the electricity grid was low because the hydroelectric power stations were all located close to existing electricity substations. Each project involved a custom retrofit but required minimal construction of new electricity transmission lines.

Although the review and approval process for each project was long, usually lasting about five years, the end result has been very popular with city residents. Revenue from power sales reduces local water rates and helps to finance improvements in water quality and supply. One of the benefits of this project was reduced air entrainment in the pipeline. The income will also help to replace 15.7 km of old pipeline with a new pressurised line, allowing installation of a power-generating turbine at the water treatment facility's outlet.



Topographical map of the mountains above Boulder, showing the locations of the hydroelectric stations.

Environment

Since Boulder's first hydroelectric plant began operating in 1985, hydropower has cut the city's coal consumption by over 72,000 tonnes/year. The five existing hydroelectric power stations generate a total of about 15 GWh/year. If this electricity replaces coal-fired generation, CO_2 emissions are reduced by 8,000 tonnes/year, based on IEA statistics for the USA's average electricity production in 1997. The addition of the two larger stations will increase the total output to about 51.8 GWh/year, saving about 28,000 tonnes/year of CO_2.

The local environmental impact of this project has been minimal because most of the water supply facilities were already in place. The units themselves are low profile and do not interfere with local activities and amenities; indeed, one unit is situated within a municipal park and another within an open-space area.

Boulder maintains a minimum flow of water in Boulder Creek, set by the state wildlife board to protect local flora and fauna. The city also donated $12 million of water rights to help maintain in-stream flows in North Boulder Creek for the protection of fish and wetlands in the watershed.

Overall, the project has prove that small hydropower can be run in a way that is both economically successful and sensitive to the environment.

The visual impact of the hydro installations in the Rocky Mountains is minimal.

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