NIAGARA POWER PROJECT – A SUCCESS STORY OF INTERNATIONAL COOPERATION

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1. EARLY POWER AT NIAGARA FALLS

The Niagara River has been used for power purposes for over 250 years. In 1757 a Frenchman, Chabert Joncaire, Jr., dug a tiny loop canal for a sawmill a short distance above the Falls at about the site of the present day American Rapids Bridge to Goat Island. This rudimentary power development consisted probably of a wooden overshot water wheel with a head of about 1.82 meters (6 ft) and a possible capacity of 4.5 kilowatts (kw). For comparison with Joncaire’s mill, the Niagara Power Project uses an average of head of 93 meters (305 ft) to produce 2170000 kw at the Robert Moses Niagara Power Plant.

Hydroelectric power was produced at Niagara Falls as early as 1880 when a brush dynamo was hitched to a water wheel installed in Prospect Park above the Falls to illuminate the park’s fountains with two arc lights. Excursions were run from around the country to see the wonderful electrical installation, a decided novelty in those days of gaslight and candles.

What was documented as the first public demonstration of electricity at Niagara Falls took place on December 14, 1881. Water flowed from the upper river down a canal to turn DC generator arc light machines using the 26.1 m (86 ft) drop of a paper mill shaft. This installation, halfway down the Gorge wall below the Falls, supplied the light of 2000 candles to two mills, several downtown stores, an office building, and a newspaper office.
2. COMMERCIAL POWER PRODUCED

The first large-scale output of commercial power at Niagara Falls began in 1895 when the first of the Adams Stations above the Falls started turning out electricity. The Adams plant employed a short intake canal and a 2133.6 m (7000 ft) long by 6.4 m (21 ft) diameter discharge tunnel running under the downtown section of the City of Niagara Falls. Water dropped 41.1 m (135 ft) down vertical shafts to operate the turbines rated at 3728.6 kw each. The Adams generators, pioneers in commercial production of alternating current, were still in regular use until the plant shut down permanently in September 1961.

Prior to development of large scale electric generators, the canal mentioned previously had been used to carry water to water wheels and iron turbines producing mechanical power only. The waste water from these primitive
plants gushed haphazardly in unsightly man-made waterfalls from the wall of the gorge above the Maid of the Mist Pool. The canal itself, through downtown Niagara Falls, was begun in 1853. It was progressively enlarged until the turn of the century when advances in electric power development made practical the construction of Schoellkopf Power Stations at the bottom of the gorge where they could utilize 61 m (200 ft) of the river's drop.

Twenty units installed at the Adams plant were rated at a total capacity of 80000 kw. One unit at the Niagara plant produces nearly twice as much power.

Two-thirds of the Schoellkopf plant was destroyed by a 1956 rockslide. The remaining reactivated section of the plant was served by a 1310.6 m (4300 ft) long tunnel placed in operation in 1923. This section and the obsolete Adams plant ceased operation in 1961, when the new Niagara development was capable of utilizing all of the water allotted to the United States under the 1950 U.S.-Canadian Treaty. The hydraulic canal through the heart of the city has been filled in to the original ground surface, and a portion of it now serves as an exit from the Robert Moses Niagara Parkway.

Before the disaster struck, the Schoellkopf plant was rated at 365000 kw. Until it was retired from operation, the restored portion had a capability of 95000 kw.

3. THE RIVER AND THE TREATY

The Niagara River forms the boundary between the State of New York and the Province of Ontario between Lakes Eire and Ontario. The river, only 58 kilometers (36 miles) long, drains four of the five Great Lakes – an area equal to about one-twelfth of the area of the continental United States. Average flow in the river is 5800 cubic meters per second (m$^3$/s) (202000 cubic feet per second, cfs), day and night throughout the year, making it among the world’s most dependable sources of water power.

The United States and Canada, which share the Niagara waterway, signed a treaty in 1950 to preserve the beauty of Niagara Falls and make more water available for power production. The Niagara Diversion Treaty of 1950 established priority for scenic, navigation and domestic purposes and allows remaining flow to be used for power generation. About two-thirds of the average Niagara River flow is available for power generation and is shared equally by Canada and the United States.

The Niagara River drops spectacularly 53.6 m (176 ft) at the Falls but it also drops some 18.3 m (60 ft) through the cataracts above the Falls and about 23.5 m (77 ft) through the various rapids below the Falls. The Robert Moses
Niagara Power Plant is located downriver from the Falls and below the last rapids so that its tailrace is approximately 1.2 m (4 ft) above the level of Lake Ontario. The project's intake above the upper rapids is about 2.7 m (9 ft) below the level of Lake Erie. The headwater at the river intake averages elevation 171.6 m (563 ft) above sea level. The tailrace below the Robert Moses Plant averages about elevation 76.2 m (250 ft). In this way the project takes advantage of 95.4 m (313 ft) of the 99.4 m (326-ft) difference in water levels between the two lakes.

Fig. 2
Great Lakes System Profile (FRENCH)

1. St. Marys River
2. St. Clair River
3. Detroit River
4. Niagara Falls
5. Lake St. Lawrence
6. Lake St. Francis
7. Lake St. Louis
8. Montreal Harbour
9. Gulf of St. Lawrence
10. Lake Superior
11. Lake Michigan
12. Lake Huron
13. Lake St. Clair
14. Lake Erie
15. Niagara River
16. Lake Ontario
17. St. Lawrence River
18. Atlantic Ocean
4. THE NIAGARA PROJECT DEVELOPMENT

The loss of the Schoellkopf plant resulted in a power shortage on the Niagara Frontier, endangering thousands of manufacturing jobs. In response to the emergency, Congress passed the 1957 Niagara Redevelopment Act, directing the Federal Power Commission to issue a license to the New York Power Authority to fully develop the United States share of the Niagara River’s hydropower potential.

Established in 1931 by Governor Franklin D. Roosevelt and the state Legislature, the New York Power Authority is a nonprofit, public-benefit corporation. It finances project construction through bond sales to private investors and repays the bonds with proceeds from operations. It does not use tax revenues or state credit.

Under the direction of Chairman Robert Moses, crews began work in 1958. An 11,000-strong construction force brought the Niagara project to first power in 1961. In just three years, the Power Authority was producing electricity from the Niagara project, then the largest hydropower facility in the Western world.

Located about 8 kilometers (5 miles) downstream from Niagara Falls, the New York Power Authority’s Niagara Project is the state’s largest electricity producer. The project has two main components: the Robert Moses Niagara Power Plant and the Lewiston Pump-Generating Plant. Together they can generate more than 2,400 megawatts (MW) of electricity.
Two intakes tap water from the river 4 km, (2.5 miles) above the Falls. Each below-the-surface intake has 48 slotted harmonica-like openings that draw water into the project’s twin conduits. These concrete conduits carry river water some 7.2 km (4.5 miles) under the City of Niagara Falls and the towns of Niagara and Lewiston to the Niagara project’s forebay in Lewiston. Each is as wide as a four-track railroad tunnel. As much as 1419375 liters per second (375000 gallons of water a second) charge through each conduit and empty into the Forebay. From the Forebay, the water goes to both the Robert Moses and Lewiston plants.
Fig. 4
Niagara River (FRENCH)

1. Sir Adam Beck Reservoir
2. Lewiston Reservoir
3. Pumping Generation Station
4. Sir Adam Beck-Niagara Generation Stations
5. Lewiston Pump Generating Plant
6. Robert Moses Niagara Power Plant
7. Maid of the Mist Pool
8. American Falls
9. Horseshoe Falls
10. Canadian Niagara Power Intakes
11. Becks Intakes
12. Welland River
13. International Niagara Control Structure
14. NYPA Intakes
15. Grass Island Pool
16. Tonawanda Channel 42% of Flow
17. Chippawa Channel 58% of Flow
At the west end of the forebay is the Niagara project's main generating facility, the Robert Moses Niagara Power Plant. Its 13 turbine-generators together produce up to 22,750,000 kw. Water enters the plant intakes and drops 30 stories through steel penstocks to the turbine-generators. Wicket gates inside the scroll case control the flow. The turbines rotate at 120 revolutions per minute and discharges water to the lower Niagara River. A stainless-steel shaft connects the turbine to a rotor, which produces electric current through the generators.

The Lewiston Pump-Generating Plant on the east end of the forebay is the Niagara project's 'storage battery.' It has 12 reversible pump-generators, which can produce up to 300,000 kw. Its 769 hectare (1900-acre) reservoir holds up to 83.9 billion liters (22 billion gallons) of water. It was built to use the United States' maximum share of Niagara River water allotted under the treaty.

During the night, when consumers use less electricity, the treaty allows more water to be diverted from the river. Lewiston's units then operate as pumps, transporting water from the forebay up to the reservoir. The stored water stays in the reservoir until it is needed for power production.

In the daytime, when electricity use rises and less water can be diverted from the river, the Lewiston pumps are reversed to become turbine-generators similar to those at the Robert Moses facility. Penstocks funnel stored water from the reservoir through the Lewiston plant to spin the generators at 112.5 revolutions a minute to make electricity. The water flows back into the forebay to be used again at the Moses plant where it produces about four times the amount of power generated at Lewiston.

Electricity generated at the Robert Moses and Lewiston plants travels in underground cables to the switchyard, located between the two facilities. Power runs on 21 transmission lines from the switchyard to electric utilities throughout the Northeastern United States.

Since original construction, various upgrades have been made to the project. Between 1983 and 1987, the runners of the LPGP turbine/generators were replaced in order to improve pumping efficiency of the units. Beginning in 1991, a RMNPP turbine/generator efficiency upgrade program was initiated involving all 13 units. This program was completed by 2006.

5. OPERATIONAL CONSTRAINTS

The principal operational constraints for the Niagara project fall into four categories: Treaty scenic flows; power generation scheduling; natural conditions such as flows, wind, and ice; and, ice management.
The required minimum scenic flow over Niagara Falls is 2832 m³/s (100000 cfs) during the daytime of tourist season from April through October. During tourist season nighttime and non-tourist season, from November to March, the required minimum flow is 1416 m³/s (50000 cfs).

Power generation scheduling has changed in recent years. NYPA scheduling is now subject to an Independent System Operator (ISO). This involves bidding generation in a day-ahead and an hour-ahead market.

The rate of flow of Niagara water depends on the height of Lake Erie at Buffalo and this fluctuates slightly from day to day with the direction and intensity of the wind. A prolonged westerly gale over Lake Erie produces a substantial increase in flow of the Niagara River. Conversely, a strong east wind drops the river level by holding water in the lake. Wind-caused variations can occur in the course of a few hours, but seasonal variations in the lake level due to rainfall seldom exceed two feet. The maximum flow of record in the Niagara is only slightly less than twice the minimum. The minimum flow of record since 1860 was 3553 m³/s (129000 cfs) in February 1936 and the maximum was 7243.5 m³/s (255800 cfs) in May 1929. This fluctuation is trivial in comparison with the seasonal ups and downs of most of the world’s great rivers where high flows run 20 to 30 times the minimum. For example, the Columbia River has a ration of 35-1 and the Mississippi River 25-1.

The United States and Canada work together to “winterize” the Niagara River. Their purpose is to minimize the impacts of ice on power production at the Power Authority and Ontario Power Generation facilities along the Niagara River.

During the winter, air temperatures on Lake Erie, west of Buffalo, can nose-dive to -26°C (-15°F). 80.5 kilometer per hour (50 mile per hour) winds can whip water into four-foot waves on the river. In these conditions ice forms quickly and builds sometimes to a thickness of 4.57 m (15 ft) on Lake Erie. To help prevent massive runs of lake ice into the Niagara River, the Power Authority and Ontario Power Generation place a 2682 m (8800-ft) long ice boom at Lake Erie’s outlet to the Niagara River. The boom consists of floating steel pontoons linked together and anchored to the river bottom with steel cables. It helps establish a stable ice cover on the lake, typically one to two feet thick, allowing water to continue flowing into the Niagara River.

When ice does travel into the river, icebreakers patrol the Niagara, breaking up and directing ice chunks over the Falls. The Power Authority operates the William H. Latham and the Breaker, and Ontario Power Generation operates the Niagara Queen. The 69.9 metric ton (77-ton) Latham is particularly efficient, with a 50.8 cm (20-inch) knife on the underside of its keel and a rounded steel hull. The vessel runs onto the top of ice slabs; its weight crushes the frozen masses. During period of heavy ice formation, the icebreakers operate 24 hours a day.
6. CLOSING REMARKS

The New York Power Authority’s Niagara Power Project is the largest renewable electricity producer in the state and the fifth largest in the nation. It meets more than 10 percent of New York’s power needs. Since 1961 this hydroelectric facility has transformed the energy of the Niagara River and Niagara Falls into a treasure trove of economic benefits, saving the state’s residents and businesses hundreds of millions of dollars a year in electricity costs. The project’s power is among the lowest-cost in the state. It supplies energy to job-producing industries, steel making to ice cream packing, along the Niagara Frontier and in other parts of New York and to adjacent states.

Fig. 5
Niagara Power Project
(FRENCH)

Fulfillment of the primary purpose of the 1950 Treaty – preservation and enhancing the scenic beauty of Niagara River – is insured by remedial works constructed under the direction of the International Joint Commission by Ontario Power Generation and the U.S. Army Corps of Engineers and paid for by the two power entities.

The remedial works consist of the Chippawa-Grass Island pool control structure and excavations and fill on both flanks of the Horseshoe Falls. The dam-like control structure regulates both the flow of the river over the falls and the water level in the pool where the intakes to the Canadian power plants are located and is slightly downstream from the Power Authority’s intakes. The remedial works also assure a uniform curtain of water over the crest of the
Horseshoe Falls, permitting withdrawal of water for power purposes without altering the beauty of the Falls. Another important advantage – reduction in total water volume over the Falls and maintenance of uniform flow – will reduce erosion, prolonging the life of the Falls. The remedial works were funded by Ontario Power Generation and the Power Authority.
SUMMARY

The Niagara River forms the boundary between the State of New York and the Province of Ontario between Lakes Erie and Ontario. The river, only 57.9 km (36 miles) long, drains four of the five Great Lakes – an area equal to about one-twelfth of the area of the continental United States. The average flow in the river is 5800 m$^3$/s (202000 cfs) day and night throughout the year. This makes it among the world’s most dependable sources of water power.

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The Niagara Power Project’s design for power generation from its Robert Moses Niagara Power Plant and Lewiston Pump-Generating Plant and Reservoir is discussed. Rules of operation and interaction with other uses are outlined. Operational constraints on power generation include: treaty scenic flow restrictions; power generation scheduling requirements between the Power Utility Companies and the independent system operators; natural conditions such as flows, wind, and ice; and, ice management. The United States and Canada work together to “winterize” the Niagara River. The purpose is to minimize the impacts of ice on power production at their respective generating facilities along the Niagara River.
Keywords

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