DESIGN AND INSTALLATION OF A STRATEGICALLY PLACED ALGAE MESH BARRIER AT OPG PICKERING NUCLEAR GENERATING STATION

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Abstract

Ontario Power Generation's Pickering Nuclear has experienced a number of events in which attached algae have become entrained in the water intake costing approximately $30M over the 1995-2005 period as a result of deratings, Unit shutdowns and other operational issues. In 2005-2006 OPG and Kinectrics worked collaboratively on evaluating different potential solutions to reduce the impact of algae on the station. One of the solutions developed by Kinectrics included a strategically placed barrier net designed to regulate algae flow into the station intake. In 2006, Kinectrics designed and installed the system, the first of its kind at a Nuclear Power Plant in Canada. The system was operational by May 2007. OPG completed an effectiveness study in 2007 and concluded the barrier system had a beneficial effect on reducing algae impact on the station.

1. Introduction

Ontario Power Generation (OPG) is an Ontario-based electricity generation company whose principal business is the generation and sale of electricity in Ontario. OPG is one of the largest power generators in North America providing a total capacity of over 22,000 megawatts (MW) [1]. OPG owns and operates 3 nuclear generating stations including Pickering Nuclear Generating Station (PNGS) located on the shores of Lake Ontario just east of Toronto in Pickering. Pickering NGS consists of Pickering A and Pickering B together generating 3,100 megawatts (MW), making it one of the world's largest nuclear generating facilities [1]. Maintaining reliable production from this facility is critical to meet customer demands.

Ontario Power Generation's Pickering B Generating Station has experienced a number of events in which algae, predominantly *Cladaphora,* has become entrained in the water intake causing operating problems ranging in severity from unit load reduction to complete station shutdown [2]. During the eleven year period from 1995-2005, generation losses related to algae for Pickering B were estimated to be roughly $29.7M or $2.9M per year on average [3] (refer to Table 1). This prompted OPG to take a proactive approach in addressing the problem.

Period	Gross Production Losses (MWh)	$ Loss due to Algae
1995	294,557	$ 14,580,554
1996 - 2000	81,816	$ 4,049,892
2001	49,715	$ 2,460,885
2002	4,660	$ 230,694
2003	36,028	$ 1,783,403
2004	8,227	$ 407,258
2005	126,749	$ 6,274,094
TOTAL	**601,752**	**$ 29,786,781**

Table 1 Generation Losses at Pickering B 1995-2005 [3]

Since 2005, OPG and Kinectrics have worked collaboratively on a number of initiatives to better understand the algae problem and to develop solutions to mitigate it. One of the solutions discussed was a strategically placed barrier net off the east groin of the intake channel to reduce algae influx into the station that primarily originates from the east (approximately 80%). In 2006 Kinectrics designed and installed an algae mesh barrier at Pickering NGS making it the first at a Nuclear Power Plant in Canada.

This report provides background on the algae problem at Pickering Nuclear, and discusses the major design features of the algae mesh barrier solution. In addition, the effectiveness of the system during the first year of operation is discussed.

2. Background

2.1 Statement of Algae Problem

In warm weather conditions algae growth in Lake Ontario becomes elevated and certain wind conditions can cause large influxes of detached algae to enter the station's water intake systems. When this occurs it is defined by the station as an algae run. The ability of the station to cope with an algae run depends on the volume of algae and the duration of the event. The station is better equipped to handle a slow and steady algae run, as opposed to an event where the same volume enters the plant over a shorter period of time [4]. Wind speed and direction are the key environmental factors that determine the magnitude of the algae run, and can vary significantly from day to day especially during storm events.

When algae enters the station, it accumulates on the travelling screens and filters threatening the cooling capacity necessary for the station's turbine condensers. The threshold of the screen house equipment to handle algae depends on its condition, an optimally maintained screen house will have a higher threshold than a poorly maintained one [5]. When the threshold is exceeded, the pressure differential increases and the screens become overloaded and trip [5]. When this occurs, the capacity of the cooling water is reduced forcing the station to de-rate power output. This is defined by the station as an algae event and can have a serious impact on lost revenue (Table 1).

Since 1972, there have been at least 42 events at Pickering when algae, predominantly *Cladophora* (Figure 1), has caused operating problems ranging in severity from unit load reduction to complete station (4 unit) shutdown [2]. Twenty-five of the 42 events have occurred in the last five years (2001 to 2005), with 15 in 2005 alone. In general, algae incidents occurred in the later part of the year, August through December, although some events have occurred earlier in the year (eg June 1995 and May 2001) [2].

Figure 1 *Cladophora* (attached algae).

2.2 Algae Characteristics at Pickering NGS

As shown in Figure 2, algae distribution from east to west of Pickering NGS is predominantly along the shoreline [6]. According to the airborne CASI image, the algae density along the shoreline ranges from 32 g/m^2 to 190 g/m^2 (dry weight). The density appears to reach its maximum closer to shore (shallower) and declines as water depth increases.

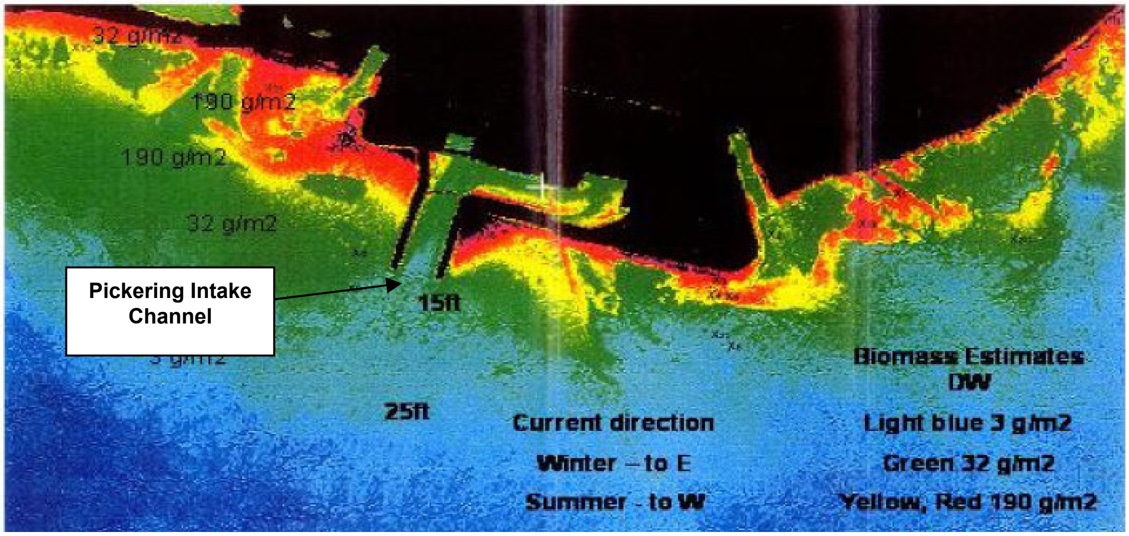

Figure 2 CASI image of Pickering station showing areas with *Cladophora* [6]

In 2005-2006, OPG and Kinectrics worked collaboratively on an investigative study to understand the movement patterns of algae following detachment. An evaluation of the environmental conditions were reviewed prior to and during each algae event including wind speed and direction, lake current speed and direction, and lake temperatures. The results of the study indicate the wind direction during algae events is predominantly from the north east direction at speeds over 20 km/hr (80%), and lake current direction is from east/north east for 100% of events reviewed [4]. More recent data concluded that the key environmental factors are wind and current direction, and the majority of algae events occur when algae runs are from the east [4].

The information captured during the investigative study allowed OPG and Kinectrics to better evaluate design solutions for reducing the impact of algae on the station.

3. Algae Mesh Barrier Solution

In 2005-2006 OPG and Kinectrics evaluated a number of design solutions to address the algae issue. One of the solutions considered was a barrier net placed across the intake structure. Mesh barriers are used extensively in the US to reduce fish impingement at Power Plants as part of the USEPA regulation 316(b). The systems in place are in a wide variety of operating environments from protected water areas to harsh lake conditions (i.e. Lake Michigan). Although they are primarily used for fish impingement, they are reported to be effective at trapping debris such as algae.

The idea of placing a mesh barrier across the intake structure at Pickering Nuclear was rejected due to the high flows in the intake channel (greater than 2fps). A unique approach to this solution was to strategically place the net, at a location where the algae originates from (and lower flows), so as not to jeopardize the safety of the station from the consequences of net breakage.

As discussed in Section 2.2, algae events originate predominantly from the east. Preliminary analysis suggested that a mesh barrier positioned off the east groin of the intake channel would result in an algae reduction of 30% or higher from entering the station. This technology was reviewed by OPG along with other solutions such as equipment enhancements and operational changes [2]. The solutions were evaluated against a number of criteria including installation cost and estimated effectiveness. The algae mesh barrier was a preferred option for Pickering NGS due to its relatively low cost and moderate estimated effectiveness. In addition, the solution could be installed and operational very quickly without station interruption. This solution was to be considered as a trial or experimental basis, with the intent that the net could be extended if preliminary results indicated a reduction in algae influx.

The principle of the net operation is to delay or regulate the flow of algae into the station. As discussed in Section 2.1, the station can cope better with a slow and steady algae run as opposed to a sudden quick algae run of the same volume. As the net becomes loaded with algae, it was anticipated that the algae will pass through the net, move around it, or be redirected towards the east when the wind direction changes [6]. In each case, the net is expected to have a positive impact on the station.

Kinectrics submitted a proposal to OPG in September 2006 to design, supply, and install a strategically placed algae mesh barrier off the east groin of the Pickering intake channel. OPG prepared a business case based on the estimated algae reduction and decided to proceed with the solution immediately (September 2006).

3.1 Project Overview

In September 2006, Kinectrics was awarded a contract to design, supply, and install an 85m (280ft) mesh barrier net system off the east groin at Pickering NGS. The use of a mesh barrier to regulate (delay) algae flow into a nuclear power plant intake was the first of its kind in Canada. The main objectives of the project included:

- Determine the optimal net design and placement to reduce algae influx into the station
- Perform a risk assessment including consequential analysis of failure of the barrier net design
- Obtain all necessary approvals for installation including regulators, OPG internal approvals
- Safely install the barrier net
- Evaluate effectiveness

3.2 Engineering Design

The design process was complex and required meeting a series of design requirements that included engineering constraints (civil, mechanical, hydraulic), nuclear safety, public safety, and regulatory approvals including the Department of Fisheries and Oceans, Ministry of Natural Resources, and Transport Canada. The design also required the net to be easy to install, remove, maintain, and clean on a regular basis. The final design underwent an extensive risk assessment to ensure the design would have no negative impact on station operations.

As part of the engineering design, Kinectrics reviewed similar systems in the US through extensive discussions with suppliers and engineers at power plants, and site visits to utilities in the US who currently operate barrier nets (i.e. Consumer's Energy in Ludington Michigan who have been operating the system for over 20 years).

The major design tasks for the algae mesh barrier system included determining the optimum design of the following:

- Positioning of Net
- Net Panel
- Piling and Connection

3.2.1 Positioning of Net

The optimum location of the net was determined to be off the east groin of the Pickering intake channel, as the source of algae is predominantly from the east. To determine the proper orientation of the net, hydraulic modeling was completed on several options. Hydraulic modeling also verified that under worst case conditions with the net fully blocked, the net would not pose a safety risk to the station such as restricting cooling water supply. The model included evaluating net orientations of 30^o, 45^o, 66^o, 90^o, and 135^o under worst case conditions (0% porosity, no cleaning/maintenance). The model results were expressed for different flow conditions (0.5, 1.0 and 2.0 ft/s) with currents approaching from either the east or west [7]. A storm scenario was assumed to occur when the flow approached the groins at 2.0 ft/s (flow in the intake channel is approximately 2.5 ft/s). The results of the modelling report [7] suggested the following:.

- The 45^o orientation off the east groin was considered the preferred option for net placement (refer to Figure 4). This orientation achieved a high collection zone with flows from the east but there was less risk with erosion (attached algae entering the station from around the net) compared to other simulations such as the 90^o angle or no net cases (refer to Figure 3).

- There is no increase in risk to the station with the addition of a net relative to present conditions. There was also no evidence of negative environmental impacts with a net in place on the east groin.

- Results with a net porosity of 75% more closely resembled that of a fully clogged net than the no net case when the flow approached from the east. In all cases, there was a reduction of the area of the re-circulating region.

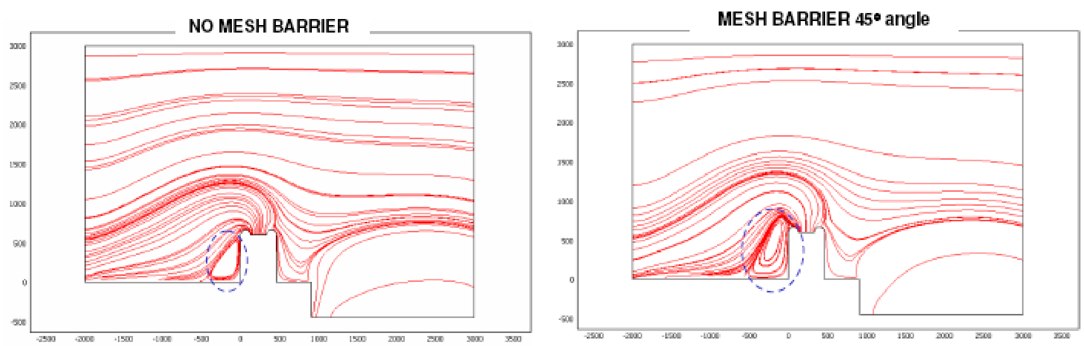

Figure 3 No Mesh Barrier in Place (left), Mesh Barrier 45o off of East Groin [7]

Figure 4 Barrier Net Location and Orientation

3.2.2 Net Panel Design

To provide 85m coverage, a total of 9 net panels were designed to cover the span including 8 ‘standard’ net panels and 1 wedge net panel which connects to the groin. The 8 standard net panels are roughly 7.6m (25ft) wide and the wedge net panel 24m (80ft) wide. Each net panel is designed to accommodate 110% of high water level plus a 1m (3ft) wave. The additional height of the net allows the barrier to stretch out allowing coverage of the water column during rough water conditions (waves <1m). Each net panel has a single float line designed to keep the net panel buoyant. As the net becomes loaded with algae the floats begin to submerge, signaling the station that cleaning may be required.

The mesh size of each net panel is 3/4” (bar) made of #18 Dyneema® twine (1.7mm diameter). Dyneema® is an extremely robust material rated up to 15 times stronger than steel and up to 40% stronger than aramid fibers, both on weight for weight basis [8]. The most common mesh sizes used in the US for fish impingement are 1/2” and 3/4” (bar), and both sizes have the effect of trapping algae. The function of the net is to delay the flow of algae through the net and thus the larger 3/4" mesh size was selected.

The framing lines of the net provide the structural integrity of the net system. The perimeter of each net panel is outfitted with 5/8” Dyneema® rope. A 1/2" long link chain is sewn directly into the bottom framing line, which is designed to keep the net weighed down on the lake bottom.

3.2.3 Piling and Connection Design

A total of nine steel pipe piles (12”) embedded into the lakebed provide the mounting structure for the net system. Each standard 7.6m net panel is fastened between a set of steel pipe piles spaced approximately 7.6m apart. The piles protrude above the lakebed and are roughly 2m below the lake surface to avoid ice issues and navigational hazards. The connections between each pile and net are made using standard marine shackles. These are relatively easy to install and remove underwater by divers. Refer to Figure 5 for an illustration of the net system and how it is connected.

A marker buoy is connected to the net at each pile location (9 buoys). Each buoy is outfitted with a solar light in order to comply with the relevant marine transportation requirements.

3.2.4 Groin Connection

To form a complete seal between the net system and the groin (armourstone), a wedge net panel was designed to connect directly to the groin and the first pile. The first pile was installed as close to the groin as possible at approximately 13-m (40 ft). The wedge shaped net was connected to the first pile and the groin where it is connected by a chain to a set of concrete anchors installed on top of the groin. Figure 5 shows an illustration of how each net panel is integrated into a continuous net system. It also shows the wedge shaped net panel that connects to the groin of the intake channel.

Figure 5 Diagram of Net System with Typical Net Panels and Groin Connection

3.3 Summary

The 85m algae mesh barrier was installed in May 2007, at a 45 degree angle off the Pickering NGS east intake groin (Figure 6). The barrier net was inspected, cleaned, and repaired as necessary during its first season in operation and removed in December 2007.

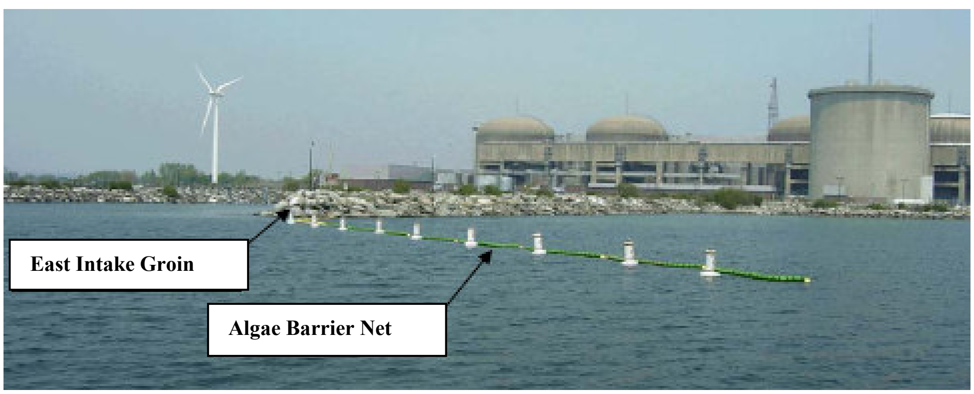

Figure 6 Diagram of Net System with Typical Net Panels and Groin Connection [6]

3.4 Estimated Effectiveness

According to a report prepared by OPG, the algae mesh barrier had a beneficial effect on Pickering NGS during its first season in operation in 2007 [6]. This report analyzed the effectiveness of the net for algae traveling near the shoreline from the east towards the station. Various methodologies were used to determine the effectiveness of the barrier net including an assessment of algae material accumulating in front of it, screen house bin data, and the results from a Radio-tag Release and Tracking Study completed by Kinectrics (2007), which focused on the number of released tags collected by the net [6].

The key points outlined in the evaluation report [6] are listed below:

- Effectiveness appeared to be variable during the season depending on environmental factors (wind speed and direction, etc.).
- Highest effectiveness was observed in August when algae detachment occurred. The effectiveness during this period for algae traveling near the shoreline from the east towards the station was estimated to be 30%.
- The net appeared to be most effective during short algae runs lasting only a few days (48%), while effectiveness dropped for events lasting 10 days or longer (15%) [6].
- After the detachment period in August, effectiveness declined. After October no algae accumulation was observed.
- Generation losses at Pickering B in 2007 related to algae, could not directly be linked to net behaviour, as many factors influence algae related losses such as screen house equipment condition.
- The Radio-Tag Release and Tracking study concluded the barrier net is in a good location, allowing the net to interact with 67% of algae traveling near the shoreline from the east.

The effectiveness of the algae mesh barrier during its second season in operation has not yet been determined.

3.5 Lessons Learned

During the first two seasons of operation, OPG and Kinectrics have gained extensive knowledge and experience related to the design, operation, and maintenance of the algae mesh barrier system. During this time a number of lessons learned have been identified including the following:

- *Extension of net system for improved effectiveness:* It is expected that the effectiveness of the system can be enhanced by extending the net further south by at least 100m.
- *Reduced cleaning requirements:* Through two years of operation, the net has behaved as a ‘self-cleaning’ system, where algae attached to the net is removed and washed away during high wind or storm events.

- *Maintenance procedures:* Routine maintenance and repair of net panels are completed in-situ by divers on a weekly basis (weather pending). This minimizes the risk of net panels having to be removed for major re-work.

- *Managing height of net panel with fluctuating lake levels:* The net panels are designed to accommodate high water level plus a 1m wave. As a result, in low water levels the netting has a tendency to gather slack at the lake bottom making it a potential wear area for the net. Kinectrics addressed this in the design by keeping the slack suspended in the water column using a buoy system. There are other solutions that may be considered as well such as the addition of a second float line to the net panel.

4. Conclusion

Kinectrics safely installed the algae mesh barrier in May 2007. During its first year in operation, the net was considered to be effective at reducing the impact of algae runs on the station. The net just concluded its second season in operation (May-December 2008), and an extended net is expected to be installed again in May 2009 to address not only algae but fish impingement.

During the first two years in operation, OPG has gained significant operational experience and has identified a number of potential areas for improvement. One option to increase effectiveness is to extend the current net further into Lake Ontario [6]. This would increase the coverage area for regulating algae flow into the station from the east. There is also a desire to further understand the behaviour of algae through initiatives such as source and movement studies, algae growth and accumulation measurements, and screen house bin data collection and content analysis [6].

OPG and Kinectrics continue to work together on initiatives focused on improving the understanding of the algae problem and reducing the impact on the station.

5. References

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