Preventing Jellyfish Attacks on Electrical Power Plants in Kuwait:

An Innovative Solution

Eng. Muhammad R A A Jamal*, Eng. Abdulaziz S A N Aldhafeeri* and Dr. Humoud Alqattan*

**PAAET, HIE, Head of Electrical Power Department.*
***PAAET, HIE, Electrical Power Department.*
****PAAET, HIE, Electrical Power Department.*
Corresponding author: Mu~~o~~hammad R A A Jamal

Abstract

During the recent couple of years, significant jellyfish blooming occurred in the bays among the power plants along the Arabian Gulf coast, which was an indication for Kuwait and other countries in this region. These blooms often result in blocking the cooling water intake and clogging of the filters and pumps, which leads to the shutdown of generation units and outages. Presently, shift the focus from reaction to prevention. Such a problem can't be solved only with the existing manual monitoring methods. The following paper argues for an inexpensive and humane solution by combining, a) a LiDAR-based detection system for aquatic species that functions under water, b) drone-based surveillance, c) image processing software, and d) a water jet array that shoots the water in the direction of the intake bay to move jellyfish away from it. LiDAR system, which is a real-time monitor enabling detection of such cysts concurrently, and aerial drones, which serve a supplemental role in producing the imaging. The software provides sophisticated images of the data compilation, distinguishing blooms and estimating concentration and progression. When a jellyfish bot is detected over the main entrance flow, the jet array is run to generate crossflow that will prevent the jellyfish from getting into the intake area. Such a system is able to provide power plant operators with advance information about possible jellyfish invasions and block the way for these murky creatures to prevent stoppages or interruptions of operations.

Introduction

Jellyfish are ancient marine creatures that have existed for over 500 million years, long before dinosaurs roamed the earth. There are more than 1,500 species of jellyfish, from those as small as inches to those larger than humans, inhabiting every ocean around the globe. Although they lack brains, these simple animals are quite visionary and have set standards that humans have tried to match ever since. Although, in general, jellyfish is a slow swimmer, prevailed by sea currents, it occasionally accumulates on the surface of water in large blooms, including many individuals.

These blooms become a great environmental and industrial danger when they occur close to coastal regions. Jellyfish have the potential to threaten fishing operations owing to their tendency to be caught in nets and damaged. They have been spotted penetrating aquaculture pens, causing fish a great deal of discomfort and suffocation. Tourists who prefer to swim in waters free of stinging nettles frequently avoid beaches with excessive jellyfish mass washups. In scenarios where jellyfish blooms enter cooling water intake channels and clog the circulating pumps, there is a lot of danger that the plant's steam cycle will trip and cause serious consequences.

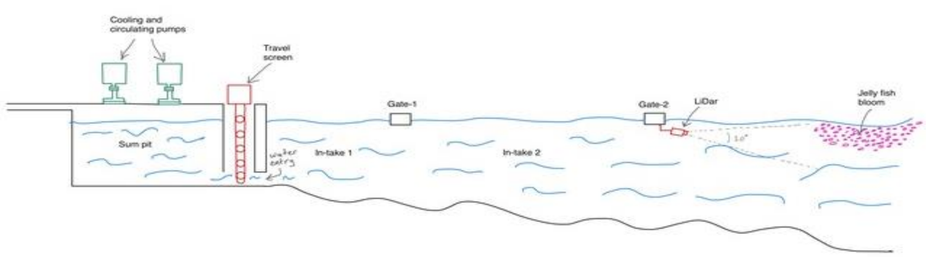


Figure 1: Jellyfish-Fightin' Desalination Plant

The Arabian Gulf has been a center for developing swarms of boggling jellyfish in recent years. Along the lines of the Al-Zour Power and Desalination Plant in 2017, jellyfish formed such a great congregation to the point of obstructing the intake screens. Personnel had to temporarily pause the cycle pump operations to curve them out, and the disturbance continued for multiple days. Many more occurrences of the same have been reported from other institutions all over the Gulf. The mechanisms that lead to these blooms have not been unriddled yet, with theories of rising ocean temperatures due to climate change, overfishing of jellyfish predators, increased coastal nutrient runoff, and the accumulation of aquaculture aquatic farms in the marine environment being among the most popular.

Uncertainties on the accurate timing of jellyfish blooms, together with the disastrous effects they inflict on power generation units in affected locations, should be given deeper thought and strategic planning via continuous monitoring and early warning systems. Through this, countermeasures would find a way to enter the delicate intake structures that the jellyfish presence threatens. This paper presents an integrated solution that utilizes multiple advanced technologies to autonomously trace the jellyfish blooms in advance and then automatically alter the intake of sea water to not let the jellyfish enter the power plant.

Jellyfish Bloom Phenomena

While the jellyfish themselves have survived largely unchanged for hundreds of millions of years, marine biologists have observed a marked global increase in severe jellyfish blooms over the past few decades (Mills, 2001). The suspected reasons are associated with the diverse ecological consequences of marine pollution, which originated from the multitude of human activities throughout the oceans and coastal ecosystems around the world. According to the leading theory, climate change, by means of higher ocean temperatures and acidifications, has provoked increasing levels of plankton that provides the jellyfish with their primary food supply (Purcell, 2005). As water temperatures rise, the conditions become more suitable for blooms of plankton, which in turn provide a glut that jellyfish take advantage of to hasten their population growth.

Moreover, the overfishing of various kinds of species that prey on jellyfish also removes an original control mechanism, so the jellyfish population keeps growing without being held back (Purcell et al., 2007). In addition to those fertilizers from the fields, coastal cities and industries also fuel thick plankton blooms, which jellyfish feed on. Similarly, more fish farming occurs worldwide, which is yet another source of water runoff that leads to more plankton production, which benefits jellyfish life cycles (Lucas et al., 2014). This human environmental impact is likely to give rise to an ambush-oriented bunch of creatures like jellyfish with high potential to reproduce very fast as the external eggs and larvae can be freely distributed in the water.

Sometimes, when these reproductive blooms occur, millions of separate jellyfish clump together into dense groups and gather at the water surface. Some of it is a natural part of the jellyfish lifecycle, whose blooming and frequency have significantly increased in response to a favorable environment that was impromptu created by climate change and other human pressures on nature (Rowley and others, 2020). These large, seasonal spawning flashes frequently deliver dynamics so complex to forecast that they can become catastrophic when they hit unexpectedly, even in well-protected shore areas (Mariani, 2018; Lo, 1991). The coastal plants, as well as the desalination facilities, are especially vulnerable because they're completely clogged by ropy blooms of jellyfish when they try to use the seawater for cooling, and this means they have to stop their work until some physical cleaning can make the work go on.

The Problem: Impact of Jellyfish Blooms on Power Plant Operations

For coastal power plants like those in Kuwait, jellyfish blooms pose a safety risk when they enter and obstruct the critical cooling water intake systems (Mills, 2001). These water inflow systems draw in a large volume of seawater, which is sometimes millions of gallons every minute, for the turbines' steam condensation purposes to power up the most efficient power production cycle (Purcell et al., 2007). A considerable backlog or casualty to this cooling water stream can immediately result in an unexpected full plant shutdown as temperatures go beyond the workable restrictions.

The screening areas installed by intake pipes include grated barrier systems that remove solid materials and marine life from the inflow so as to ensure the proper work of the pumps, piping, and heat exchanger system. First and foremost, thick concentrations of jellyfish that hold millions of individuals can 100% cover and clog these screening zones within minutes when they come in counterflow. The stream circulation loop is being disrupted since the flow is interrupted and the water levels drop immediately to allow for a temperature increase within the steam cycle. This normally requires a controlled emergency shutdown method to avert catastrophic overheating and damage to the major plant constituents like the turbines, condensers, and boilers (Rulley et al., 2020). Running intake systems while they are full of jellyfish masses is occasionally extremely certain because the powerful pumps quickly shred the soft gelatinous bodies and create an impenetrable filtered mat. This eventually causes the pump to fail or the piping to burst.

During these clogging episodes, employees are required to take action by using the most complicated and dangerous procedures involving the removal of jellyfish populations from the blocked screening settings (Lo, 1991). For some types of toxic blooms, the biomass is vast, and these do not only hurt the workers but could also sting their tents, thus making this job very difficult. However, as long as the filtering area is not completely cleaned of jellyfish, which can take a day or two to fully clean, the entire plant is unable to proceed safely (Pearce, 2005). As data on jellyfish blooms increases annually and expands to many coastal regions, partly due to climate and other environmental factors, the likelihood of such forced outage events for power facilities also goes up.

The current situation: Current Jellyfish Monitoring and Response Practices:

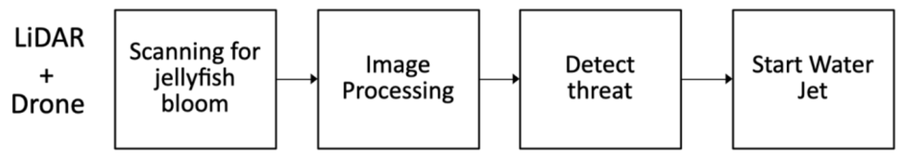
Most power plants currently have minimal capability to detect jellyfish blooms before they arrive at the intake screening areas. Currently, used protocols usually focus on the playfield and adjacent bay fists by plant personnel who watch the surrounding water. If this is the best-case scenario, the estimated arrival time of the concentrations will be no longer than a few minutes before numbers are clogged into the intake grates (Mills, 2001). This short notice of time is not enough to respond effectively and prevent jellyfish from entering the primary treatment plant through pipes. Some areas utilize spotter boats to do more upstream sailing, but since blooms travel in all directions, unpredictably, and often randomly, there is still no guarantee. These short-range checkup efforts are also energy-intensive (Mariani, 2018). The unpredictable movements of bobbing jellyfish and their sudden rapid emergence from the shallow make it very difficult to reliably achieve sustained scanning from close distances.

Once a bloom has been identified as approaching an intake area, the response in this regard would be cut short. Air cannons and hoses, which are positioned in the most likely places to disperse the jellyfish, are not effective at all, according to a study by Lucas et al. (2014). The high animal density of jellyfish blooms makes the evacuation of the grates physically impossible once they cover them with their bodies. Devices based on acoustic stimulation of low frequency are promising, although the inconsistency of their performance is a serious challenge as the jellies may just push through the stimulus barring the way (Purcell, 2005). Marine experts also agree that in such high noise, this could become damaging for other animals, not only jellyfish but all wildlife around the area. In terms of physical barriers, like nets, they offer a certain level of protection but are cumbersome to rapidly deploy.

Implementing appropriate protocols of prevention or mitigation is not one of the coastal electricity stations' priorities upon the occurrence of jellyfish blooms. Of course, traditionally practiced methods such as visual surveying, the use of spotter boats, and simple dispersal methods have totally failed to cope with dense patches of jellyfish swarms, which instantly clog inlet screening systems (Rowley et al., 2020). On the rise, jellyfish blooms are already a normal situation, and their occurrences with more intense levels are expected to be more frequent, with their population number increasing. Based on this, factories situated on the seashore can prepare for constant forced outages and unexpected shutdowns for the sake of blocked intake channels (Lo, 1911). During these events, there are extended periods of reduced production that require jellyfish masses to be manually cleared from the impellers. This is a very trying and perilous situation for the plant operators who are exposed to the long tentacles and their magnitude.

The continuous unplanned outages can attract huge monetary costs for the utilities from the lost revenue. Also, they can increase the operational expenditures of the system by leaps and bounds in case any more labor is required and maintenance is carried out (Lucas et al., 2014). The occurrence of additional emergency power outages from the coastal facilities may be the most serious of all, since it already starts posing a serious threat to the overall system resilience and stability after being combined with other adverse events if the events worsen (Purcell, 2005). Among the rapidly emerging threats, this phenomenon stands out, and now the coastal power grids with a high frequency of jellyfish blooms have put it at the top of their mitigation agenda.

Solution: Proposed Jellyfish Monitoring and Diversion System



Underwater LiDAR Monitoring

The cornerstone of the proposed system is an array of LiDAR (light detection and ranging) sensors installed on the seabed surrounding the intake areas. LiDAR technology utilizes pulsed lasers in order to perform rapid surveying and 3-D imaging of underwater areas on an extremely detailed layer. It is capable of detecting small marine objects as well (Mariani, 2018). Each LiDAR sensor has a particular coverage area assigned to it, and all the sensors are networked with each other in order to supply overlapping bands of detection up to 1km along the intake channels. Jellyfish Aggregation Tracking: The test part has the shape of a cuboid, which shows the 3D array of space around the objects, such as groups of jellyfish that are found in the monitored water (Purcell et al., 2007). Instead of the limited resolution and recognition of objects given by conventional optics and sonar, whose identifying targets are the basis of forecasting jellyfish blooms, a LiDAR scanner has provided a highly precise characteristic, which is a prerequisite in this process.

Aerial Drone Monitoring

Besides providing full coverage scanning of the ocean bottom, the system now allows drones in the air to conduct regular high-altitude patrolling as an alternative (Rowley et al., 2020).

One of the major drones carries daylight-visible and infrared cameras; the first is being used to distinguish thermal signatures and the visual appearance of jellyfish blooms, and the second is being used to learn the pattern and anomaly detection techniques, which can form the basis of further drone development. The main objective is to pinpoint the beginning of the blooms when their size range is beyond the 1km swath of the seabed LiDAR sensors' detection capabilities. Jellyfish white away buoyant blooms while searching them in the surface currents that jellyfish adhere to and use as a course of movement due to their mode of weak swimming (Lucas et al., 2014). Working together, the devices underwater and the airborne sensor network provide continuous 360-degree turning coverage, which provides nearly complete detection of jellyfish blooms from all angles.

Imaging Analysis and Tracking Software

The data collected by the LiDAR and drone monitoring systems is processed by advanced software with a built-in machine vision sphere with artificial intelligence and recognition for patterns. This software has been fed with enormous data sets, and thereby it has been able to automatically distinguish and determine the number of various jellyfish species in aggregation and also track the movement direction and speed of their vectors (Mills, 2001). The software uses the recorded data of the bloom in the affected area to find it in the intake canals. It then projects the bloom's future path based on its current speed and direction (Purcell, 2005). The system then immediately sends a risk warning to the plant operators if the projected bloom trajectory presents a high likelihood of hitting the intake area within the warning time frame defined. This stops the outbreak of a dangerous scenario that can be tackled with real-time solution measures.

Water Jet Diversion Array

The final protective element is a set of powerful seawater pump units in the intake channel on the night of the full moon. Every pump feeds a nozzle multi-direction array that is capable of ejecting a high-velocity jet stream that targets the same surface of the water as the intake zones (Lo, 1991). Then, upon receiving a derivation signal from the detection systems, members of plant staff can instantly take an appropriate action that would involve the redirection of the airflow by means of the involving water jets. The angles and the current intensities are configured dynamically each time based on the latest data from the monitoring systems to make sure they most effectively blur and move jellyfish blooms away from the vulnerable intakes with the least intrusive effects on the surroundings. Different from the other strategies that strive to physically block the bloom or potentially harm the jellies by noise deterrents, this creative approach successfully repels the movement of the bloom in an easier way by changing local flow patterns of water in a strategic manner (Purcell et al., 2007). The genetic makeup of jellyfish colonies drives them to follow the currents' path when they first emerge as weak swimmers.

Integration and Operation

Under the control of the centralized operation, the system of detection and diversion is fully functional. Ultimately, when dispatched, the array and drones will collect and send the security camera's footage to the software for interpretation (Mariani, 2018). LiDAR sensors map in real-time a 3D image of everything in the underwater areas within 1km of intake channels, providing the position of the obstacles (Purcell et al., 2007). While the aerial drones patrolling the area use both visible and infrared cameras to observe for patterns that denote potential jellyfish blooms (Rowley et al., 2020), it covers the dual approach of using both airborne and waterborne methods that ensure early detection of contaminants from below and above the water (Lucas et al., 2014). The data gathered from all these sensors is streamed to the central monitoring station, where the advanced AI software conducts image analysis to locate, categorize, and track any jellyfish clumps if they are present.

If the image processing algorithms code up a bloom trajectory as hazardous, an automatic notification is sent out to the control center pinpointing the possible intercept location and the projected time to impact the diversion areas (Purcell, 2005). Besides ensuring sufficient time for plant operators to respond adequately, this advanced supply system utilizes predictive measures to thwart breakdown within the plants. When the bloom spectrum advanced alert is generated, the staff can activate the water jet diversion array pumps coupled with the nozzle settings of a particular bloom according to its vector details in motion. Jet streams of exceptional intensity are generated, and their course is determined via the software programming in the tracking system as the intakes' waters are intersected by ideal stream currents (Mills, 2001). In the course of this current shunting, the bloom is deflected from its incoming route before getting to the filters' screens and entrapping them with jelly masses.

Conclusion

The aggravating rate of jellyfish blooms in the Arabian Gulf region is considered an alarming threat to the routine operation of power plants in Kuwait and the neighboring countries. The main reasons for this predicament are the continuous seas and the intake of water flows. Present circumstances about observing and reacting in an emergency situation did not allow us to predict the bloom arrival and turn away densely aggregated jellyfish. The operable concept in this paper offers an environmentally friendly method using various modern technologies that are combined to automatically detect and track the approaching blooms and then gently deflect them with the help of projecting precise water jet streams to keep them at bay before they have a chance to pose a threat to plant intake areas.

Integrating a continuous/relentless LiDAR monitoring system, aerial drones' overwatch, AI-powered bloom recognition and tracking software, and a precise jet array into a single system would, in most cases, shift the response time earlier in the growth cycle. Squids are marked with a frothy bloom that can be seen up to a km away, ensuring ample time for optimal diversion and redirecting the jellies in time. Alternatively, the purpose is to block growths at the seagrass beds and prevent high encounter situations instead of adopting quick reliefs such as nets and hoses directly at the intakes. The diversion streams act in the capacity of steering streams in a favorable direction, which safely sweeps the blooms away from priority areas by mending local water flows they are commonly prone to. Additionally, by avoiding the effects of harsh marine conditions and the restoration of plant machinery, this strategy prevents environmental damage. This system was piloted in jellyfish-prone areas and would, after success, be offered to coastal regions where critical infrastructures used for power generation, desalination, and other services will be more resilient to jellyfish bloom events spurred by global warming and environmental decline.

References

Lo, J. M. (1991). Air bubble barrier effect on neutrally buoyant objects. *Journal of Hydraulic Research*, *29*(4), 437–455. https://doi.org/10.1080/00221689109498967

Lucas, C. H., Gelcich, S., & Uye, S. I. (2014). Living with jellyfish: management and adaptation strategies. *Jellyfish blooms*, 129–150.

Mariani, P. (2018). Jellyfish identification software for underwater laser cameras (JTRACK). *Research Ideas and Outcomes*, *4*, e24716. https://doi.org/10.3897/rio.4.e24716

Mills, C. E. (2001). Jellyfish blooms: are populations increasing globally in response to changing ocean conditions?. *Hydrobiologia*, *451*, 55–68. https://doi.org/10.1023/A:1011888006302

Purcell, J. E. (2005). Climate effects on the formation of jellyfish and ctenophore blooms: a review. *Journal of the Marine Biological Association of the United Kingdom*, *85*(3), 461-476. doi:10.1017/S0025315405011409

Purcell, J. E., Uye, S. I., & Lo, W. T. (2007). Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. *Marine Ecology Progress Series*, *350*, 153–174. DOI: https://doi.org/10.3354/meps07093

Rowley, O. C., Courtney, R. L., Browning, S. A., & Seymour, J. E. (2020). Bay watch: Using unmanned aerial vehicles (UAVs) to survey the box jellyfish Chironex fleckeri. *PloS one*, *15*(10), e0241410. https://doi.org/10.1371/journal.pone.0241410