Omniflex

A guide to

CATHODIC PROTECTION SYSTEMS

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cathodic protection systems

For mission-critical steel and concrete structures, including bridges, ports, wharves, tanks or industrial pipelines, cathodic protection (CP) systems are often used to protect key assets from the ongoing threat of corrosion. If corrosion levels are left uncontrolled, structures could become unsafe and face closure.

Omniflex is a global, industry-leading designer and manufacturer of CP and remote monitoring systems for both steel and concrete applications, whether they be galvanic, impressed current or hybrid systems. Furthermore, its experts can advise on system design, covering areas such as if you require phase control vs switch mode systems or what is needed for effective distributed systems or whole enterprise solutions.

What is cathodic protection?

Corrosion is a natural, electrochemical process where metals are gradually destroyed as part of two simultaneous chemical reactions. A well-known example of this is rust, where iron is electrochemically converted by oxygen and water into hydrated iron oxides. This involves two reactions, an anodic oxidation that destroys the steel and a cathodic reduction, occurring at the same time, with electron transfer between the anodic and cathodic cell through an electrolyte.

CP systems have been used to control corrosion in steel applications for hundreds of years, with it having historical uses in protecting steel ships from corrosion. In these applications, because steel is a good conductor, structures were connected to a small number of transformer rectifiers (T/Rs) each supplying high current protection of 1,500 A or more, ensuring the steel remained the cathode in any electrochemical reaction.

CP in concrete is much newer, with most concrete structures built in the 1950s and 1960s only just dealing with the issue of corrosion in recent years. Because concrete is a poor conductive medium for electricity and has a much greater resistance to current than steel, the traditional model of having a small number of TRs each supplying high current does not work. Instead, in concrete applications, structures are connected to a much greater number of TRs each supplying a much lower current, which can be as low as 10 mA. This creates a dense matrix of low current anodes to provide the necessary protection.

Methods of CP

Galvanic CP

Cathodic Protection generally comes in one of three forms. The first is a passive technique, called galvanic CP, where a buried or submerged steel structure is connected to a metal alloy with a more negative electrode potential than it, such as magnesium, aluminium or zinc. This guarantees that the metal structure is always the cathode of the electrochemical cell, and the metal alloy becomes a sacrificial anode that is consumed by corrosion, rather than damaging the structure. The anodes can then be easily replaced when needed.

Typically, galvanic CP installations are not regularly monitored, if at all, on the assumption that the simplicity of the systems will ensure their ongoing performance and protection. But in a world of increasing requirements for compliance, performance guarantees and reporting, strategic assets do require more regular monitoring. This normally involves regular physical visits to sites by experts. These sites are often located remotely and involve safety risks to access, all of which add to the ongoing cost of ensuring protection from corrosion.

Impressed current CP

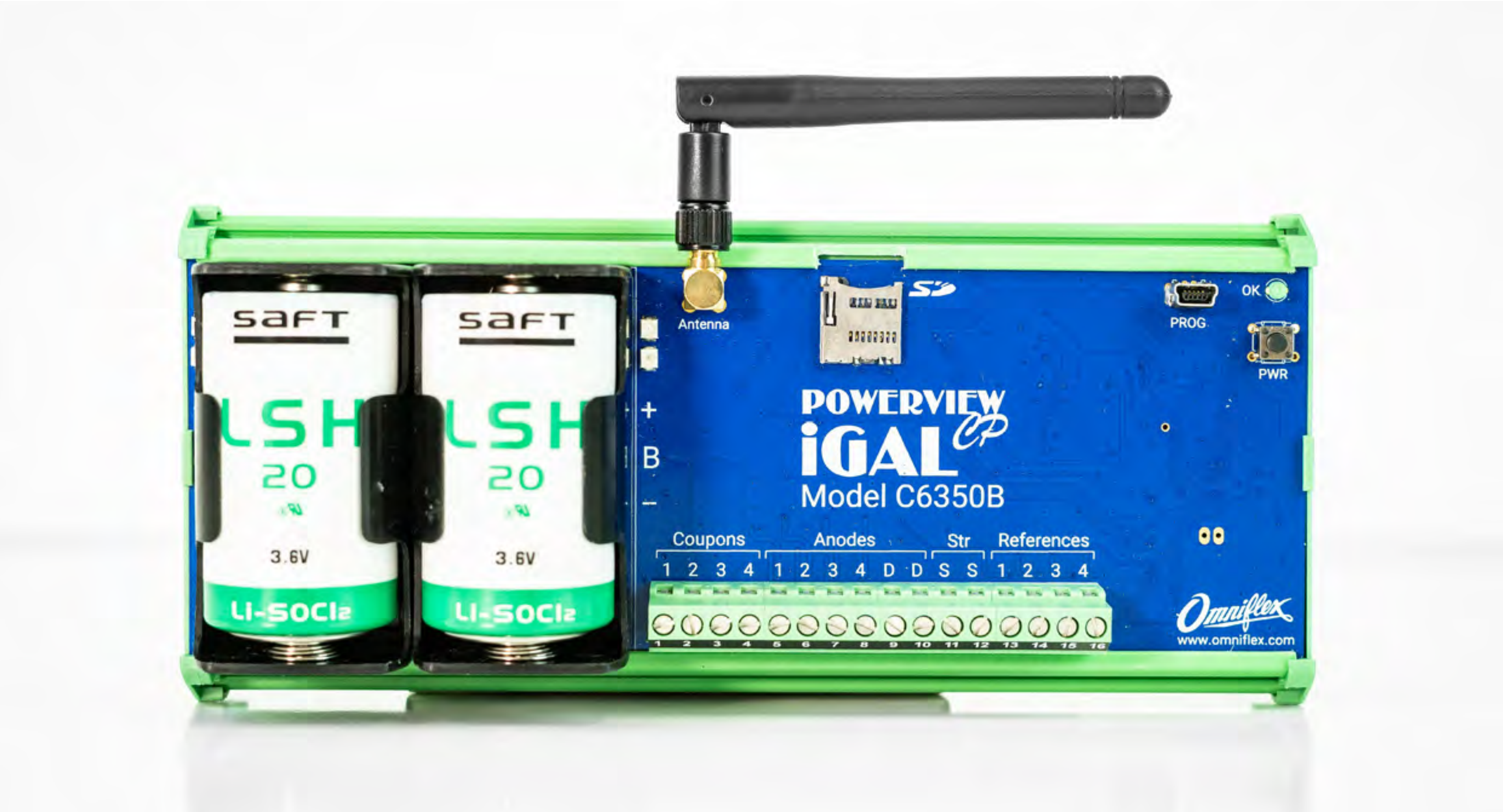
The second method is called impressed current cathodic protection (ICCP), where a current is externally injected into the structure to ensure that the structure remains cathodic with respect to its environment. Traditionally, galvanic CP systems haven't been able to offer significant protection for larger structures, like industrial pipelines, bridges or ports, so ICCP is normally used in these situations instead.

Hybrid CP

The third method is hybrid CP, which combines the properties of galvanic and ICCP protection. It works by drilling holes in the structure in a matrix and inserting the specially designed anodes directly into the structure. Then the anodes are connected using titanium wire and a temporary voltage is applied for short time to force salt migration from the steel to the anode and passivate the zone. Once the zone is sufficiently "charged", the power source is disconnected, and the sacrificial anodes are left to operate galvanically and provide passive CP protection to the structure for many years.

Applying the protection either galvanically or using impressed current is not difficult. The difficulty is knowing the correct amount of protection to apply, and monitoring that the steel is correctly protected. Too much protection, and the steel could be compromised in other ways. Too little protection and the steel will continue to corrode.

Choosing the
right CP method



Galvanic installations

In galvanic CP systems, the metal structure being protected is connected to a galvanic anode that sacrifices its ions to corrosion, protecting the intended structure in the process. The resulting benefit is that the sacrificial anode, which may last anywhere from ten to fifteen years, can be replaced easier and more cost-effectively than the structure, extending the useful lifespan of the asset.

For galvanic CP applications, Omniflex manufactures and supplies iGAL, which was the world's first battery powered instrument for remotely monitoring and testing galvanic CP installations. iGAL prevents corrosion by using three common monitoring techniques and the system can measure up to four of each of these methods. For example, four anode currents, four reference-electrode voltages and four corrosion-coupon currents can be measured.

iGAL also allows users to remotely disconnect anodes from the structure to carry out tests, such as instant-off potential and depolarisation, which can take days to complete using traditional methods. Users can remotely set up iGAL to perform these tests automatically based on their preferred schedule using a web portal over a 4G LTE mobile network, and can receive the results for analysis, all without visiting the site. This can significantly improve surveillance while reducing life-cycle costs. Users can also benefit from SMS and e-mail notifications and alarms. The results are securely and safely stored and can be downloaded for reporting purposes.

For monitoring reference electrodes, iGAL uses high-impedance voltmeter technology, and for corrosion coupons iGAL features four zero-resistance ammeter inputs. This is the most direct way of measuring the rate of corrosion.

Having no mobile connectivity and no power supply available for remote monitoring systems is a common problem for galvanic CP installations globally, particularly for industrial pipelines in remote locations. This is why Omniflex developed its Teleterm SW1, an IoT-focused satellite-based remote monitoring module for the global CP market. This can be equipped to the iGAL and is ideal for use in a variety of applications, such as galvanic CP installations on highways, bridges and pipelines in remote locations, enabling satellite-based remote monitoring and control where there is limited mobile connectivity and power supply.

A recent case study of the iGAL/SW1 combination has been its deployment for the monitoring of a galvanic cathodic protection installation of a steel culvert under a highway in Far North Queensland, Australia. In this application, the system allowed asset managers to monitor the protection of the steel culvert without the need to physically visit the remote site to conduct costly and time-consuming CP testing, which could all be done remotely.

ICCP installations

For larger structures, such as pipelines, bridges and wharves, galvanic CP systems cannot normally deliver the current required to protect the asset. In cases like these, ICCP systems are often used instead. Here, the anodes are connected to a DC power source by way of a T/R most often powered by the mains AC grid, but also available with solar power.

Currently, protecting concrete structures from corrosion is a major market for ICCP applications as structures that were first built in the 1950s and 1960s now need repair and rehabilitation works. Because of differences in conductivity and resistance, ICCP systems for concrete structures must be designed differently than conventional ICCP systems for protecting steel structures. It is not viable to have a small number of T/Rs each supplying high current doses in these applications.

Where ICCP systems for steel use a small number of zones, each covering a large area, concrete systems use many more zones of protection, each covering a much smaller area. This creates a dense network of low current T/Rs (10 mA) to provide the necessary protection.

Types of **T/R**

Phase control vs switch mode

There are two main technologies currently used to control the output voltage or current of T/Rs. The first is phase control technology, where the AC power itself is controlled through a large AC transformer to produce a controlled DC output to the anodes. The second is switch-mode technology, where high frequency circuits convert the AC power to the DC output very efficiently and cost effectively. Phase control T/R's are mostly used in larger ICCP systems with outputs greater than approximately 150 Amps, and switch-mode technology is better suited to smaller currents driving more individual zones or protection, as found more often in concrete ICCP systems and distributed steel CP systems.

Omniflex offers both phase control T/R's and switch-mode T/R's, and can advise on the best technology for each application.

An example of a dual output (15V/150A each) phase controlled Transformer/Rectifier

An example of a single output 30V/50A switch mode T/R in wall mount enclosure

Example of a 15V/400A T/R consisting of 10 individually controllable anode outputs of 40A each.

Because switch-mode technology allows smaller more compact Transformer/Rectifier modules to be produced, they are more suited to concrete applications, where the current outputs are lower, and in distributed CP systems, where this new technology is providing enormous savings in installation costs due to reduced cabling, and lower operating costs due to the shorter distance between the T/R and the anodes.

ICCP systems are designed to stay in operation for decades, protecting assets over long periods of time. This is particularly important when it comes to protecting critical infrastructure that is facing an increasing risk of damage due to ongoing potential corrosion and that is expensive to replace. It is common today to see structures that were designed 40 or 50 years ago with a 50 year life expectancy being rehabilitated and having cathodic protection installed to extend their life for a further fifty years.

Structures that are key targets for life extension are steel and concrete wharves. Major ports such as NSW Ports and Port of Melbourne, two of the largest port operations in Australia have both embarked upon major life extension projects that involve significant cathodic protection programs.

In traditional phase controlled ICCP systems, a single high current T/R connected to a high number of anodes might be used to provide protection to a large area of a structure. However, this has its drawbacks as, if you lose an anode in the system, you may be able to detect a rise in output voltage but not be able to identify the zone responsible.

For these applications, Omniflex's A Series blade T/Rs are designed to stack side-by-side, meaning that significantly more of them can fit into the same panel space as a single traditional 100 A T/R, with each blade providing 10 to 200 A depending on requirements. With each blade connected to a significantly smaller number of anodes than traditional systems, it is much more straightforward to identify any zones where there is a drop off in protection.

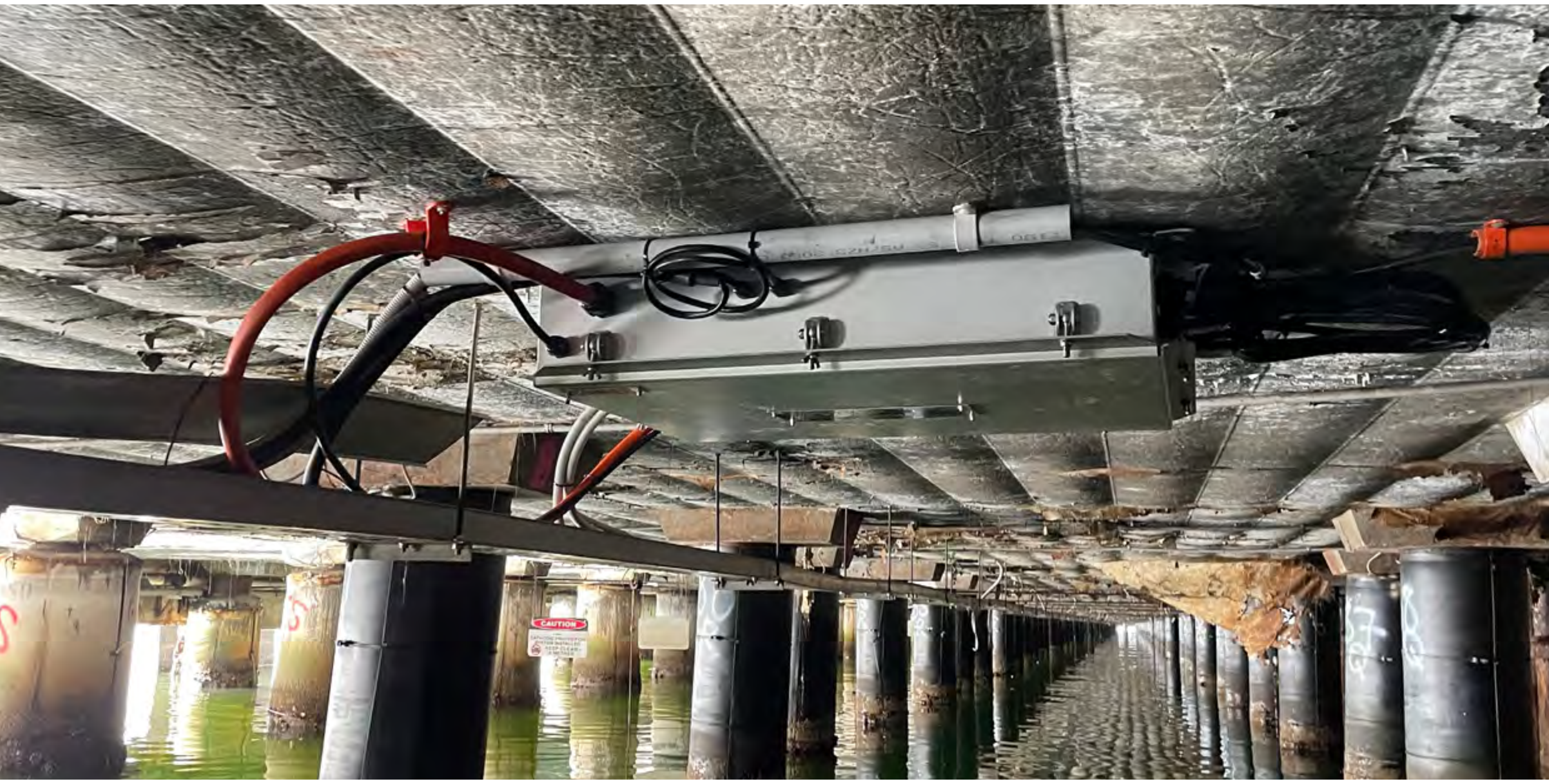
Omniflex's B Series flat T/Rs are also ideal for providing high current protection for large structures. Like the A Series, B Series T/Rs provide current between 10 and 200 A depending on requirements, but they are flat, making them best suited for wall mounting.

Industrial pipelines

Industrial pipelines are a major market for ICCP systems, often with hundreds of kilometres of steel structure protected by T/Rs installed every 30 to 40 km. Typically, to test ongoing protection, instant-off tests are performed using reference electrodes that are installed alongside the pipeline every kilometre, but this can be time consuming and laborious to perform. It also creates the possibility for manual transcription and data inputting errors, which is where replacing them with remote monitoring and control systems can be extremely beneficial for operators and asset managers.

PowerView C1 Test Post Remote Monitoring Unit

Swanson Dock West
a customer case study



One of the under-wharf T/R's at Swanson Dock

Swanson Dock is a container shipping port facility in the Port of Melbourne, which is Australia's largest container and cargo port. When the Port of Melbourne undertook rehabilitation of the port's structures, including Swanson Dock, it engaged Omniflex to help deliver the project.

Distributed Cathodic Protection Architecture

Because Swanson Dock is an active container wharf, with lots of cranes and trucks moving on top of it on an ongoing basis, there was no space to safely run cables or install T/R boxes along the 900 m long wharf. This meant the only viable option was to opt for a distributed CP system mounted under the wharf itself. Omniflex provided a PowerView CP system comprising of 20 IP68-rated stainless steel enclosures mounted under the wharf, delivering a total of 4000 Amps of CP to 80 water anodes, protecting the steel piles and sheet steel wall. The concrete decking is protected by 98 individually controlled concrete zones supplied by switch-mode T/R's and 400 reference electrodes, resulting in a fully remotely monitored and controlled ICCP system that provides protection for the 900 m long wharf.

The distributed CP system Omniflex provided significantly reduced the need for divers to regularly visit and inspect the system, leading to a decrease in downtime and ongoing labour costs. This is in addition to the increased convenience provided by the remote monitoring technology, as it meant system data could be accessed whenever required instead of relying on divers' availability to conduct manual inspections.

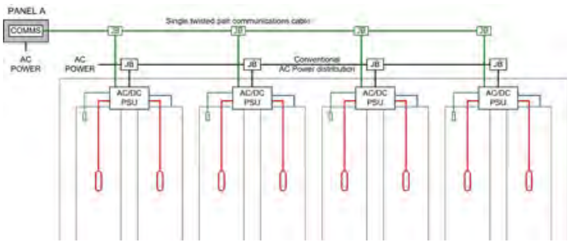
The ongoing operational nature of Swanson Dock meant that the only viable option was to **install a distributed CP system** mounted under the wharf itself and use remote monitoring technology to **collect ongoing system performance data**.

Access to under-wharf T/R's

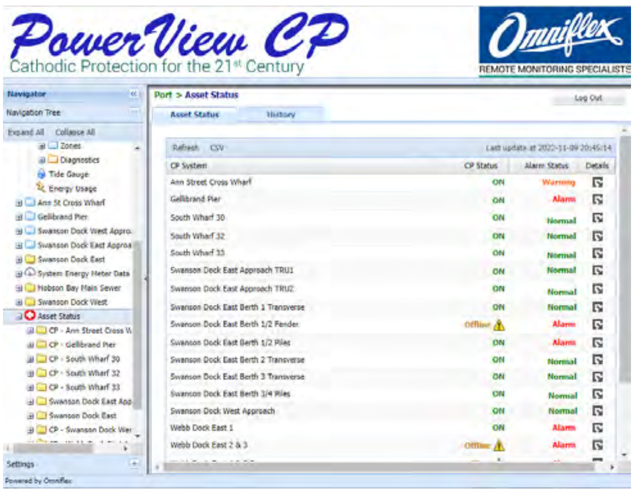
As well as energy savings made as a result of installing a CP system based on modern up-to-date technology, Omniflex's system also resulted in substantial cabling cost savings, amounting to more than $1m.

Ian Godson, the lead consultant on the project, commented,

"The savings would not have been possible without the Omniflex technology."



Distributed Cathodic Protection Architecture



Hybrid CP installations

Both galvanic CP and ICCP rely on the principle of ensuring that the steel remains more negative than its surroundings. If the steel is more negative than its environment by 800 mV, it can be safely assumed that corrosion of the steel will have been halted. However, this is particularly challenging when dealing with structures constructed using pre-stressed concrete.

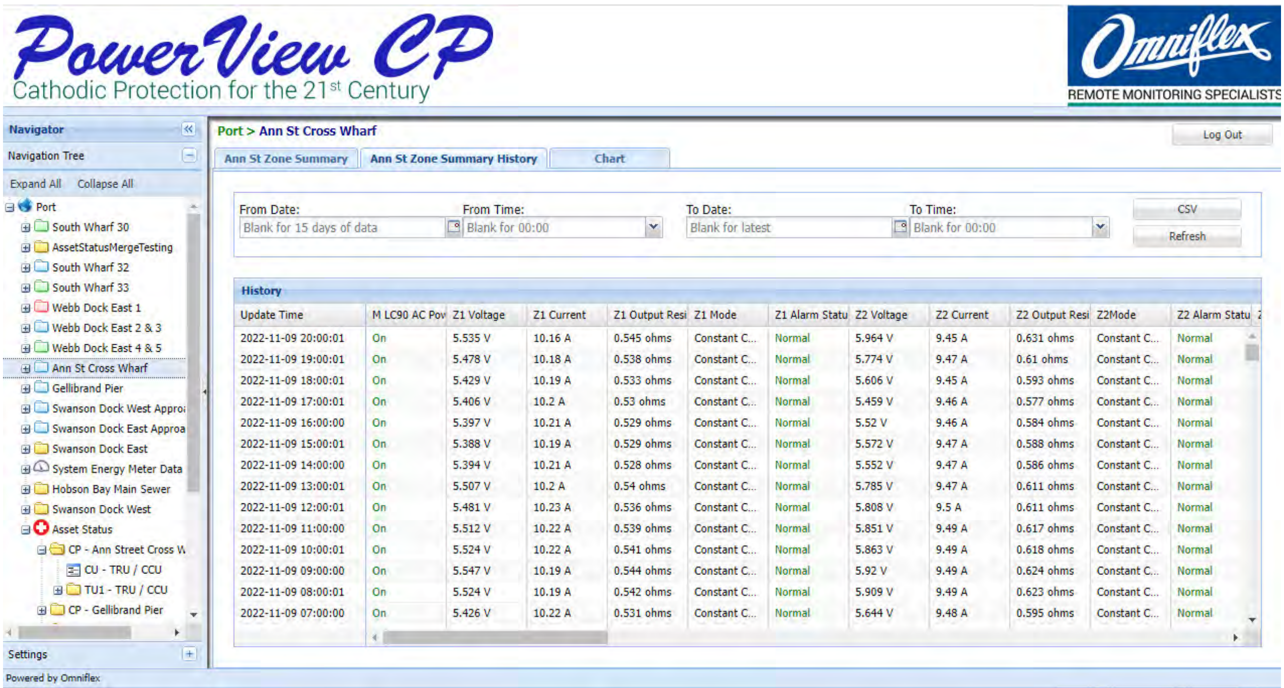
For pre-stressed concrete, high tensile steel reinforcing rods are put under tension prior to pouring the concrete . This presents a problem when using CP systems on these structures because the high tensile steel is prone to hydrogen embrittlement where the crystalline structure of the steel can be compromised, causing it to lose tensile strength and snap. For this reason, it is vital that the voltage applied to the steel is carefully controlled and doesn't cause it to be over 1 V more negative than its environment, so that hydrogen evolution does not occur.

Hybrid CP is ideal in applications where the structure is too large for traditional galvanic protection, but where you do not want the ongoing current from an ICCP system, for example an explosive environment. In hybrid CP, anodes are installed into the concrete in a dense matrix, with each providing passive galvanic protection after an initial charge period, forcing salt migration from the steel to the sacrificial anode. The charge phase is carried out using a portable T/R, which Omniflex supplies, and this can then be removed later during the galvanic protection period.

Using this method allows larger structures to take advantage of galvanic protection in a way that was not possible until recently. However, because the technology is relatively new, there is still some uncertainly about whether it can be used to protect assets from corrosion over a period of 50 years because it hasn't been field tested over that length of time yet. To provide asset managers with the reassurance they need, remote monitoring technologies can be implemented to monitor system performance and corrosion levels 24/7 on a permanent basis.

Benefits of

remote monitoring



Remote monitoring of CP systems offers several key benefits for enterprises and asset owners. Firstly, as regulations continue to evolve, data accessibility and transparency are becoming increasingly important, and cloud-based remote monitoring platforms provide managers with a single, easy-to-access repository for all live and historical CP data.

Secondly, by automatically monitoring and recording data relating to asset performance and system status, all abnormal events, like power outages or system failures, can be reported directly to all relevant personnel without delay. This enables site managers and engineers to take appropriate action immediately, minimising the chance of a negative outcome like high maintenance costs or having to face the prospect of unplanned downtime.

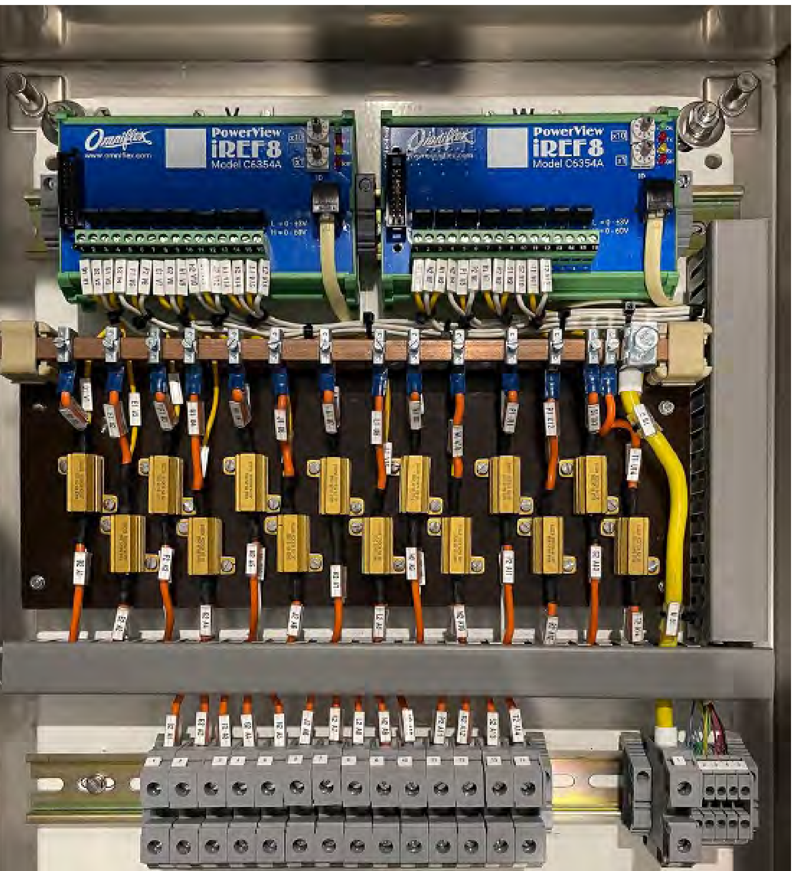
Thirdly, ongoing maintenance costs are lower when remote monitoring technologies are used to monitor CP systems. This is because there is a reduced need to physically inspect systems in difficult-to-access areas or those in hazardous environments. Furthermore, the duration of any on-site inspections is lessened because preliminary testing can be done remotely before the site visit, reducing the overall cost and minimising disruption.

> **"Remote monitoring is no longer just the most cost-effective way of gathering system data, it is now the only way to do so in many cases."**

Upgrading existing installations **with remote monitoring**

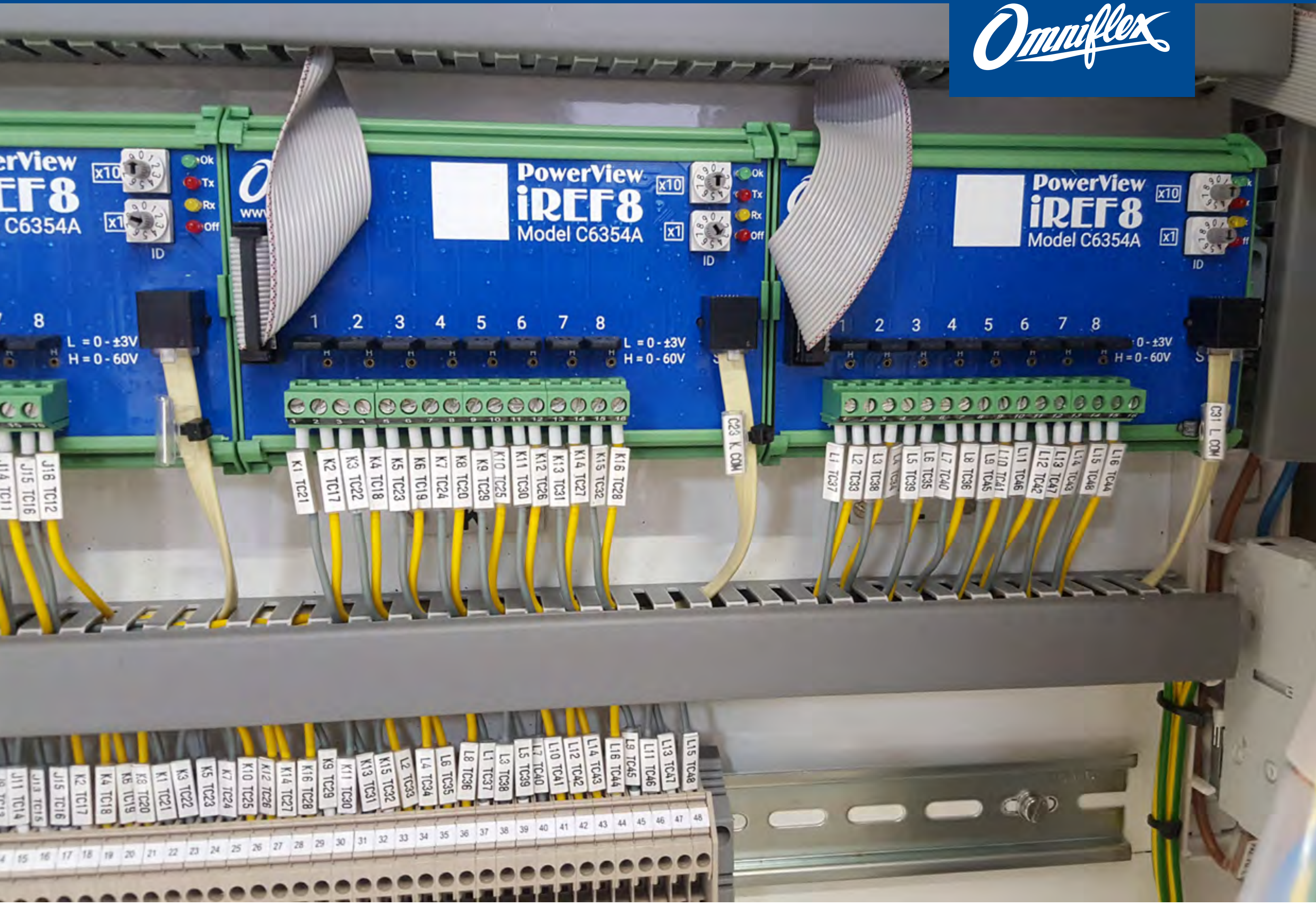
To help businesses add remote monitoring capabilities to existing CP installations, Omniflex has designed the PowerView iREF8 CP monitoring module. The iREF8 has eight isolated inputs and can monitor reference half-cells and other inputs like T/R voltages and currents. Unlike previous systems, the iREF8 also provides the ability to read all reference electrodes in a CP system simultaneously.

The new iREF8 module has eight fully isolated inputs that can be used to read reference potentials from -3 to +3 volts



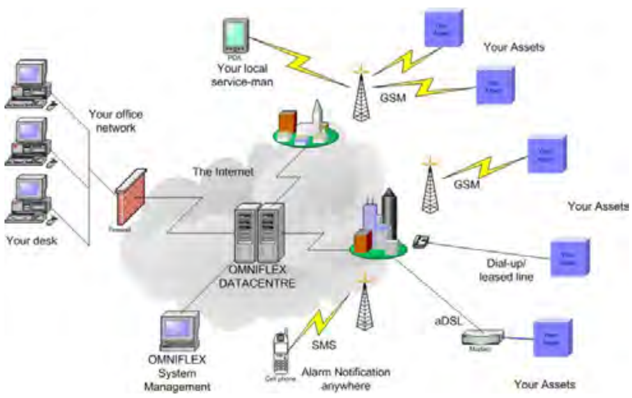
DC with an accuracy of 0.2 per cent and an input impedance of greater than 100 Mohm. This versatile module can also monitor current shunts as low as 50 mV and T/R voltages as high as 60 V making this an ideal module for monitoring existing CP systems with minimal intervention. Each input has surge protection to protect the inputs to surges in excess of 60 V.

Essentially, the iREF8 module allows operators to monitor current and voltage distribution, providing peace of mind that all anodes are connected and working as intended.



Asset managers can monitor all of Omniflex's systems 24/7 using a computer, phone or tablet thanks to its cloud-based monitoring platform, Data2Desktop. This has been particularly useful in recent years, as many people, including CP consultants and engineers, were forced to work remotely because of the global pandemic.

Data2Desktop can be used to record all system data and timestamp it to produce a chronological record of all historical data for audit purposes. The system can also automatically produce hourly reports that can be accessed remotely by any plant managers and admin staff who have the necessary login credentials. Finally, should a system error or outage occur, the system can be set up to automatically send SMS and email alerts to all relevant personnel, so the problem can be addressed as soon as possible. This is particularly important when monitoring critical systems.

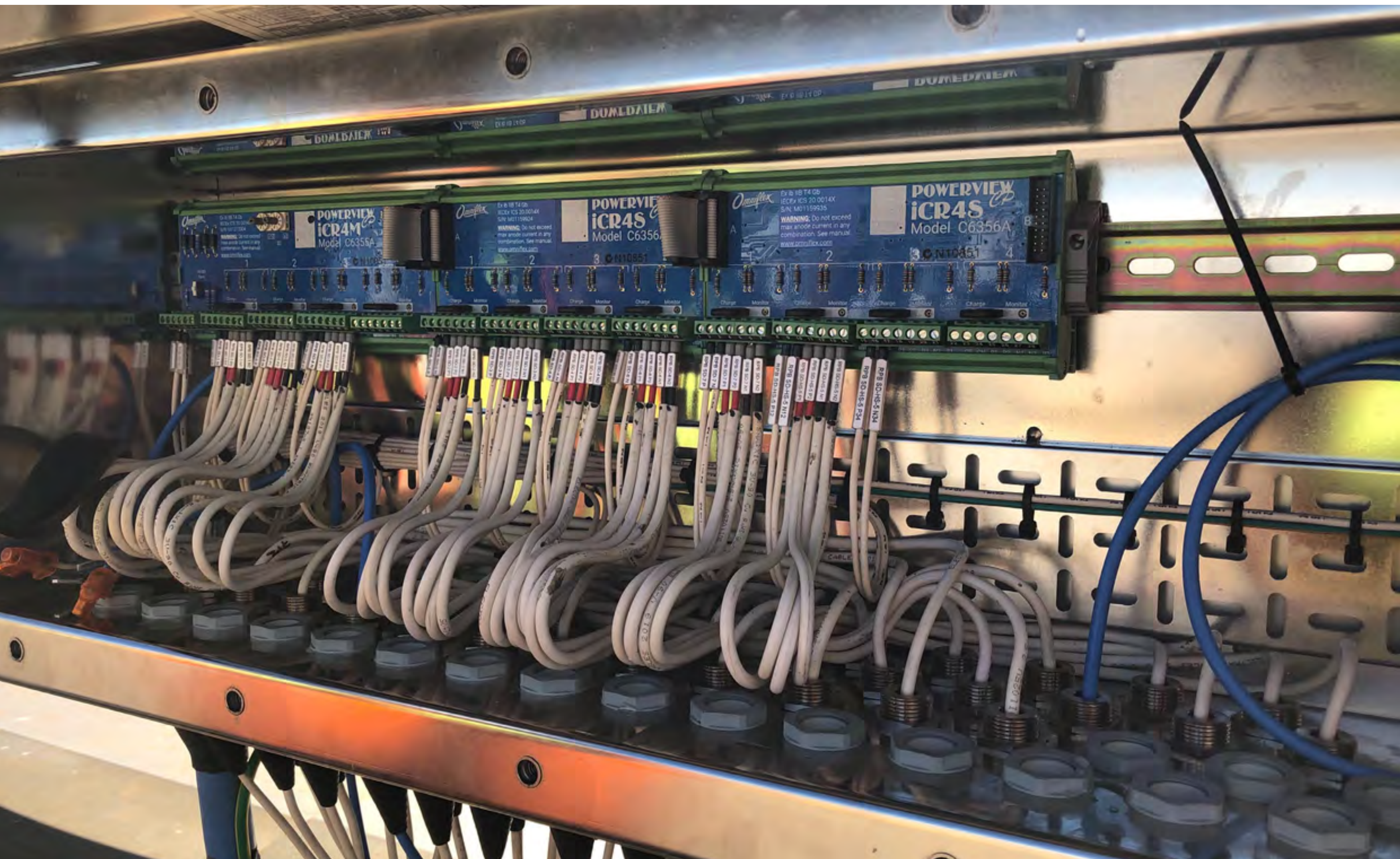


NSW Ports BLB1
a customer case study

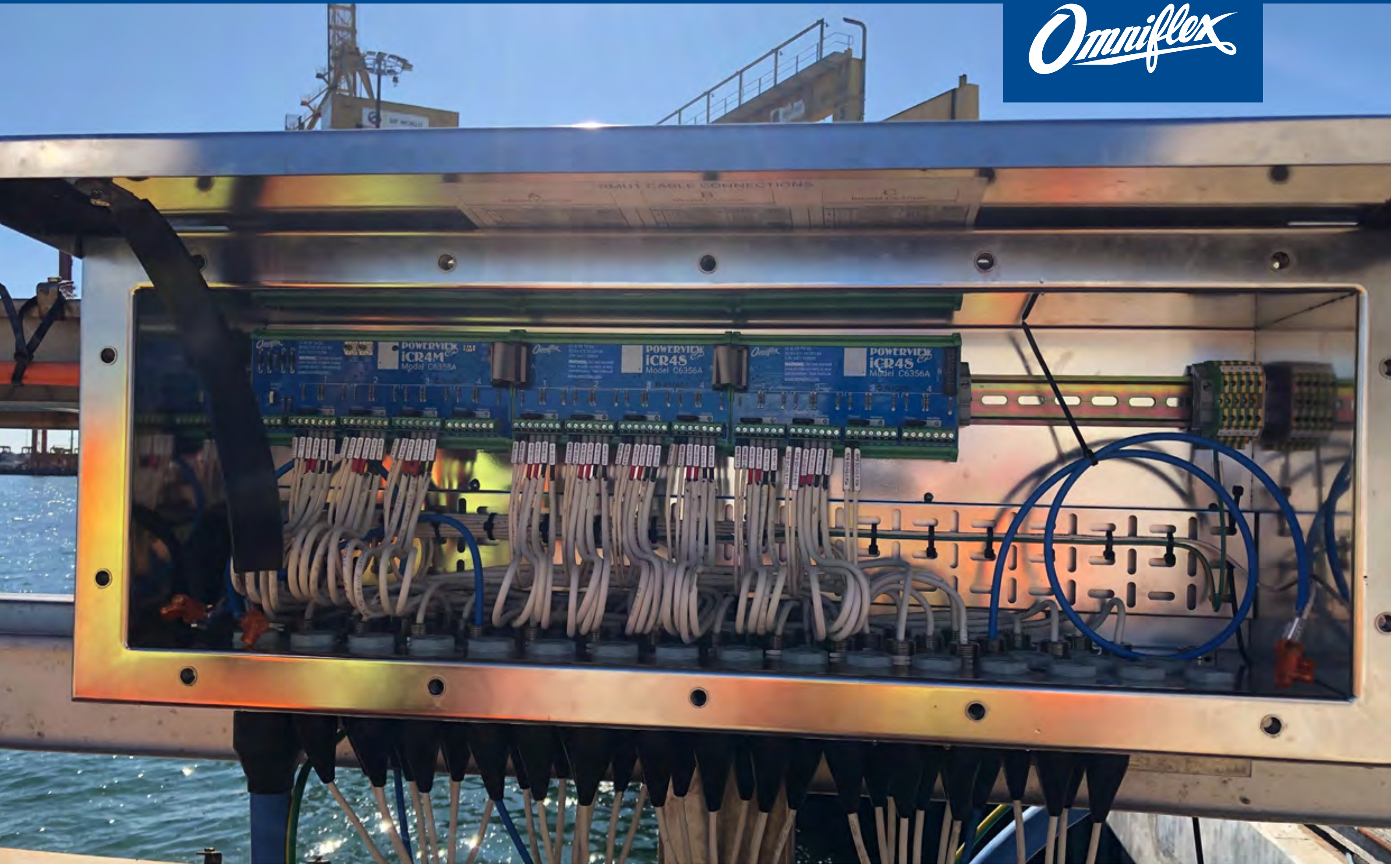
When NSW Ports embarked on a two-year program to rehabilitate the structures and combat corrosion levels at its Bulk Liquid Berth 1 (BLB1), it commissioned Melbourne-based consultancy Infracorr to deliver a bespoke CP system. Designing the system presented several challenges because BLB1 houses hazardous gas, petroleum and chemical pipelines that could be at risk of ignition if exposed to unsafe levels of voltages and currents. To safely deliver the system, the consulting firm engaged Omniflex to support the hazardous area and remote monitoring aspects of the CP system design.

BBLB1 is situated at Port Botany and houses hazardous gas tanks and pipelines. The project also included the repair of defective concrete structures which were suffering from the effects of corrosion and concrete spalling within the many pre-stressed beams and headstocks of the various bridges and catwalks at the port.

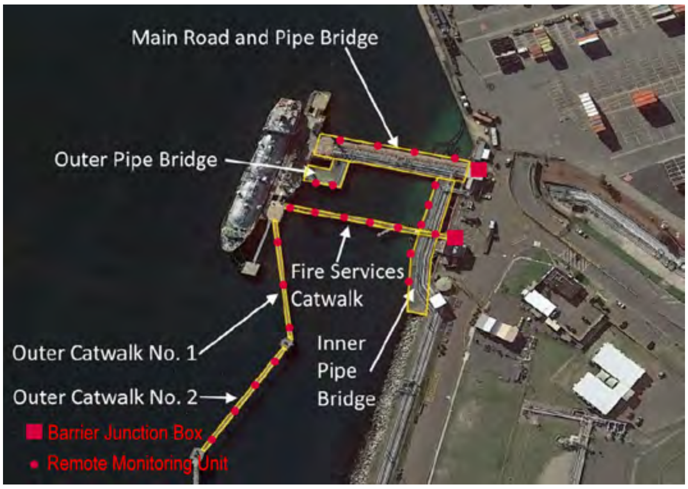
The system needed to be designed to allow for tight control of currents and voltages used throughout the site for two key reasons. Firstly, Port Botany is NSW's main bulk liquid and gas port and BLB1 is a key part of this facility, playing an active role in loading and unloading hazardous liquids and gases. These hazardous materials can be present in the environment on an ongoing basis, meaning that any stray sparks caused by excess voltages and currents on site could become an ignition source and cause a major explosion.



Omniflex supported Infracorr with the hazardous area and remote monitoring aspects of the **CP system design for the BLB1 project**.



BLB1 IECEx (zone 1) approved Remote Monitoring Units



Secondly, because many of the structures present are constructed from pre-stressed concrete, it was extremely important that all electrical currents applied were carefully controlled. As we discussed earlier, to control corrosion in steel it is necessary to make it more negative than its environment by 800 mV. However, if the charge applied results in the steel being more than 1 V negative than its environment, hydrogen embrittlement can occur. This leads to failure of the steel and catastrophic failure of the structure with long-term structural damage that isn't easily repaired.

The system designed by Ian Godson, for use at BLB1, was a hybrid CP system which would use remote monitoring technology to provide asset managers with ongoing reassurance that systems were operating as intended and corrosion levels were under control. To deliver this, Godson requested the assistance of Omniflex to advise on the hazardous area and remote monitoring aspects of the design.

Because this was the first large scale implementation of hybrid CP used within a working hazardous area anywhere in the world, some of the components required certification for the design to meet the requirements of AS60079 as an intrinsically safe certified system. Most countries have their own certification process so it can be costly and time consuming to get installations like this one certified as being intrinsically safe.

In this case, the hybrid anodes were from a UK supplier, Omniflex's technology is manufactured in South Africa and the project is in Australia, so navigating certifying bodies was challenging. However, the design was approved and certified as being intrinsically safe for use in areas classified as Zone 1 hazardous for gas group IIB in the BLB1 project, where there is the potential for exposure to volatile, flammable substances.

System performance and corrosion levels are continuously monitored 24/7 using 24 remote monitoring units (RMUs) that are situated around the site, each with the capacity to monitor 16 structures.

Ashley Rangott, Asset Manager at NSW Ports, explained, "One of the big technical challenges for the project was that there is no off-the-shelf CP system available that has certification for use in zone 1 classified hazardous areas. This meant that we had to go through the process of designing a bespoke system that met the cathodic protection objectives, including dealing with the challenge of prestressed concrete, and a system that could be certified to meet the necessary requirements under AS60079 regulations.

"Omniflex's systems are all high quality, suited to our unique harsh marine environment, and have met our quality expectations for this high-end system. The knowledge that Omniflex brought to the project ensured that the monitoring and control system was procured and operated to a high level and to our expectations," concluded Rangott.

These works ensured that the **integrity of BLB1 is maintained** and the berth remains **reliable** and **available** to handle NSW's growing bulk liquid trade volumes for the next 50 years.

Why Omniflex?

Omniflex is a global, industry-leading designer, manufacturer and supplier of CP and remote monitoring systems of any type, whether it be for steel or concrete applications and whether it be high current or low current. Furthermore, it can provide distributed systems or full enterprise solutions, depending on the project needs.

Led by their passion for problem solving, Omniflex's engineers will work with you to find the best solution to meet your operational needs and provide the best system for the job. For example, if you are not sure what type of CP system is best for the job or what kind of remote monitoring options are available to you, its team can help you.

To find out more, head to our website and read more of our industry overview whitepapers, covering topics such as wireless telemetry systems, alarm annunciators and event management, and radiological surveillance systems.