WHITE PAPER

Improving the life-cycle costs and efficiency of Impressed Current Cathodic Protection Systems

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Abstract

This paper evaluates the suitability of 21st century technology for the improvement of performance and efficiency of impressed current cathodic protection systems in Australia, and explores the opportunities that these technologies present.

Current issues such as energy efficiency, servicing costs, local support and obsolescence are analysed to identify the real benefits that may be achieved with these technologies.

The applicable risks of applying the new technology are assessed and a case is made for the fact that these technologies are now well proven and suitable for application in modern CP systems.

Cathodic Protection Current Practice

The History of Cathodic Protection

The practice of cathodic protection stems back to 1823 when Sir Humphrey Davies was commissioned by the British Navy to investigate means to prevent corrosion on the copper hulls of the Admiralty wooden ships.

The earliest attempts at impressed current cathodic protection are attributed to Edison in the 1890's, but use of impressed current cathodic protection really only became accepted in the late 1930's and the Cathodic Protection Association was first formed in 1936 to discuss and exchange information in this field. The main target application area at that time was for steel pipelines.

The well known protection criterion for steel in soils of -850 mV with respect to a saturated copper/copper-sulfate reference electrode was reportedly pioneered by Robert J. Kuhn in 1933.

The first commercially viable Cathodic Protection systems for the steel reinforced concrete market were introduced in the early 1980's. The control technology utilised for the impressed current control was tapped Transformer/Rectifier. Phase-angle controlled thyristor rectifiers were soon introduced to provide better control that and that could also be automated. Both these techniques are still widely used today.

The Science of Cathodic Protection

Understandably, the research and development on corrosion technologies has focussed on the physics and chemistry of corrosion, and techniques for it prevention, and is the realm of the structural, civil and chemical engineer.

There have been tremendous advances in the areas of materials and coatings, and the industry can be proud of the innovation and advances made in the last 50 or so years.

However, the currently available electronic systems required to perform the impressed current function can only be described as adequate, and there has been a limited investment in research and development in this area, making the typical equipment available in this industry well-proven, but dated in design and capability. This is in comparison, for example, to the process control industry where the development of electronic products into functions arguably more critical than this, has been vigorous and competitive leading to superior systems and techniques for monitoring and control.

This can be attributed to the focus of expertise in the industry, where the electronics is often viewed with some mystique and suspicion.

The Pressure to Change

As we head into the 21st century new pressures have emerged that are forcing us to consider every aspect of how we live, and cathodic protection systems will not escape this scrutiny.

Compliance and Safety

There is a sophisticated and intense focus today on compliance – especially as related to safety, and it is important for professionals to be able to demonstrate compliance with appropriate practices and standards to ensure the ongoing safety to the public and to equipment, and to mitigate the risk of liability in the case of incident.

This often means an unprecedented amount of monitoring and recording of potential hazardous equipment. Existing CP systems were never designed for ongoing monitoring and logging and the back fitting of these legacy systems proves both complex and expensive.

Cases have been seen where laboratory logging equipment has been deployed in the field to effect the necessary logging, with the commensurate excess in cost, and special skills required to operate the equipment.

Sustainability

The biggest collective challenge facing the world today is the effects of global warming and there is wide consensus that man-made factors contributing to greenhouse gas emissions need to be curtailed to ensure that man is at least not a contributor to this phenomenon, if not the primary cause.

This has created a completely new field of "**environmentally sustainable design**" and new regulatory regimes are being introduced to reduce the levels of green-house gases emitted into the environment.

Whilst there is much research being done into means of increasing the efficiency and sustainability of power generation, managing the demand side of this equation is arguably more direct and less costly to implement. That means that there is an obligation in all industries including CP to reduce wastage and improve efficiency. The motivation is that the savings gained will pay for the cost of

implementing these measures as while demonstrating a commitment to energy efficient design and operation.

Skilled Manpower Availability

CP systems require regular checks to ensure that the equipment is still functioning and providing the necessary protection. In many cases these installations are in remote sites that take significant time and cost to access. Due to the complex nature of the analysis required, it is often required for highly qualified specialists to travel to these installations to perform these checks, at increasing cost to the operator.

As the installed base of infrastructure grows older and larger, the supply of expert manpower required to performing these physical inspections will outstrip supply, forcing costs up and placing some installations at risk due to inadequate monitoring.

If means can be found to limit the physical visits by these experts to only those installations requiring intervention, an enormous saving in manpower and cost can be made.

Early warning systems capable of indicating the onset of corrosion are now available, decreasing further the requirement to attend on site at regular intervals to evaluate the state of corrosion within the structure.

The New Technology Opportunities

Switch Mode Power Technology

Traditional CP system Transformer/Rectifiers (T/R's) based upon conventional mains frequency transformers are certainly simple in design and proven in use. However, the downsides of this simplicity are the inefficient power usage of these systems, and their physical size. Typical phase angle controlled TR systems have practical efficiencies ranging in the 50-60% range, meaning that only about half of the power drawn by the system goes into the impressed current protection. The balance is lost in heat within the cubicle housing the equipment.

With each 10 ºC increase in temperature, the life of the electronic equipment within the kiosk reduces by half. The knock on effect of this is that it is often required to install heat extraction or cooling equipment to the cubicles housing the equipment, which adds to the cost and size, and reduces the system reliability.

Switch Mode Power Supply technology is now generally available that has the potential to raise the efficiency levels to around 80-90%, returning a saving of at least 60% of the wasted power. Energy bills and the contributing CO_2 emissions can be reduced by 30%. While one CP system may not seem like a large contributor to these emissions, when multiplied up by the growing number of installations, the effect can be sizable. The use of switch mode power supplies for CP systems is now common practice and has been used in CP installations with power consumption exceeding 3000 amps.

Examples of Switch Mode Power technology in common use in other industries include uninterruptible power supplies (UPS) and variable speed drives (VSD), where applications are mission critical and high demand requirements mandate high reliability products.

The Omniflex Powerterm range of Switch Mode Power Supplies is designed for the harsh industrial environment with reliability in mind. The L120P model is specifically designed for Cathodic Protection systems (zone sizes up to 8Amps), and has an efficiency rating in the order of 85%.

Switch mode power supplies operate at much higher frequencies than the mains. The benefit of this is that magnetic components (transformers and inductors) become commensurately smaller and lighter. Combined with the increased efficiency of operation the opportunity exists to reduce the size of the cubicles housing the equipment. This gives the following advantages:

- Ability to fit into confined spaces
- Ability to be installed in areas with limited ventilation such as building basements.
- Smaller panels are less conspicuous reducing the risk of vandalism.

Embedded software intelligence

Embedded software intelligence refers to the incorporation of custom computer chips at the heart of everyday products that gives them the capability to perform sophisticated calculations and logical deductions and to communicate intelligently with the outside world. Unlike desktop computers, these chips don't require regular servicing or maintenance. The reliability of these chips is so well advanced that they are commonly one of the most reliable components in the product.

Typical examples of this technology can be found in the household washing machine, controlling the wash cycles and managing load balance, and the automobile where these chips are being put to use in many tasks from managing the ABS brakes to controlling electric windows.

Most CP systems today use manual techniques for the gathering of data and analysing of the results. “Instant Off” tests require add-on sophisticated logging equipment often not suited for the harsh environment. Printed graphs are analysed off-line by experts to determine factors such as Instant Off and Polarisation Decay Values.

Manual monitoring of reference voltages often resort to a technician with a clip board and a multimeter travelling around the installations physically taking readings on a regular basis.

With embedded intelligence, a number of options become possible:

1. The equipment can communicate readings automatically to a central data store.
2. The equipment can automatically perform Instant Off and Depolarisation Testing and analyse the results, sending unsolicited alarms if conditions exceed preset limits.
3. Experts can view results “on line “ over the internet and take decision about necessary physical intervention of inspection, reducing the number of site visits required.

M2M Communications

Until recently communications over very wide areas has been a challenge, overcome only by significant investments in capital and expertise, but a new technology is steadily gaining popularity.

“**M2M**” stands for “machine-to-machine” and/or “man-to-machine” communications. M2M is the name given to a new growth market surrounding the networking of machines and devices that pervade our everyday lives. The universal concept in all M2M applications is communication with machines without geographic boundary.

M2M essentially represents a new way for you to manage your remote assets, no matter where you or they may be located.

The two biggest technologies that are coming together to make M2M a commercial reality are the Internet and the mobile phone infrastructure.

The dramatic growth of the mobile phone market has created an extensive infrastructure that is ideal for M2M. This infrastructure is reaching critical mass. The first wave of users for this mobile technology has been human. The second wave of users, predicted to be larger than the first, will be machines.

The World Wide Web

Coupled with M2M technology is the rise in popularity of web based applications.

Software as a Service (SaaS) is a model of software deployment where an application is hosted as a service provided to customers across the Internet. By eliminating the need to install and run the application on the customer's own computer, SaaS alleviates the customer's burden of software maintenance, ongoing operation, and support. Using SaaS also reduces, and in many cases eliminates entirely, the up-front expense of software purchases, through the use of a standard Internet Browser to access the application.

Users pay on an annual basis with little to no upfront costs, better matching the maintenance costing model.

For remote monitoring applications using M2M, SaaS is a natural partner to M2M, providing the collecting, storing, presentation and controlled access to information in professionally managed secure data centres with protection an reliability that cannot be matched with in-house computer equipment.

Using remote monitoring and control in CP can reduce ongoing operational costs by an order of magnitude.

Assessing the Risks

Obsolescence

Doesn’t computer controlled equipment become obsolete very quickly?

The infrastructure typically being protected by Impressed Current Cathodic Protection systems will have a life measured in decades. In the face of fast moving technology, as evidenced by the extremely short life cycle in consumer electronics, there is a concern that new technology deployed in these systems will soon be obsolete and will need replacing.

Whilst the fast pace of electronics innovation places pressure on obsolescence in markets such as consumer electronics and desktop computers, it is important to remember the reasons why. Obsolescence in these markets is customer driven, and new gadgets and computers are continuously being released and

old ones made obsolete due to customer demand. It has nothing to do with reliability of the equipment. In fact it can be shown that the more sophisticated digital electronic devices are probably the most reliable components in the typical electronics box.

This is has been proven in the industrial instrumentation marketplace, where electronics products are required to run for decades, due to the critical and stable nature of the application, and the design lifetime of the plant. Omniflex has been designing electronics products for this market for over forty years. An example of the longevity that is being achieved in this market is the company's Omni16 alarm annunciator.

Alarm annunciators are vital pieces of equipment on an industrial plant, used to warn operators of dangerous conditions developing on the plant, and are relied upon for the safe operation of most critical industrial processes. The Omni16 alarm annunciator was launched by Omniflex in 1981, and was the first alarm annunciator in the world to employ microprocessor technology with embedded software, and the first annunciator in the world to utilise solid state LED displays, when incandescent light bulbs were still the norm. The product has seen three major upgrades over its 27 year life (roughly one every decade), mainly to introduce new features and to value engineer the cost down as new technology allows. There are however a large installed base to this day of the original Omni16 alarm annunciators still performing a valuable role in protecting critical processes in the likes of the nuclear and petrochemical industries, and still supported by Omniflex. This Omni16 product is currently the only alarm annunciator approved by the nuclear industry for use in the UK, where nuclear storage site life times can be quoted in excess of 150 years!

The use of intelligent chips embedded into industrial products is a proven technology that has been around for decades. The current chips are just more capable and more reliable than they have ever been.

Products with intelligence are permeating every aspect of our lives from automobiles to washing machines, and many of these products will see 25 year life spans. This technology is being chosen specifically because of its proven long term reliability in these applications.

Many people think that the Internet is a recent innovation, when in fact the fundamental ideas behind the Internet have been around for over a half century. The development of what we call the Internet was started in 1957, and the backbone communications standard used on the Internet day, called TCP/IP, was introduced in 1983, and remains unchanged to this day.

Reliability

Isn't the simpler old electronics more reliable over time?

Reliability of electronics is affected by three main factors: The Mean Time To Failure (MTTF) of the individual components, the quality of the manufacturing techniques deployed, and the environment in which the electronics is mounted.

Modern electronics manufacturing has moved from larger "Through Hole" technology, where individual components each have wire leads that are inserted through holes in the printed circuit board, to "Surface Mount" technology, where miniaturised components are soldered on to the surface of the printed circuit board.

Apart from the obvious benefits of smaller size, reliability of these components is generally improved for a number of reasons:

- The manufacturing process being mainly automated, is more consistent and therefore free of defects will affect the failure rate;
- The smaller size of the components reduces the thermal gradients across the components in thermally stressed applications, reducing the mechanical fatigue.
- Modern electronic circuits are generally more energy efficient. This reduces the power consumption of the circuit and therefore the operating temperature. It is a well established rule that for every ten degrees Celsius that you elevate an electronic component, its statistical Mean Time To Failure (MTTF) will halve. In other words, if you can reduce the operating temperature of an electronic device by ten degrees Celsius, you can expect its time to fail to double.

An example of this is electrolytic capacitors which are a workhorse component in electronics devices such as Transformer/Rectifiers, and the components with the most definitive wear-out mechanism due to their construction. AT&T reliability studies have shown that under the same operating conditions, the MTTF is greater for a large power electrolytic capacitor than for a miniature electrolytic capacitor. The MTTF is typically between 10 and 20 years. Thus an increase in efficiency, with the associated decrease in heat load will increase the overall

lifecycle of CP systems while reducing energy consumption.

Serviceability

Aren't simple electronics products easier to service?

This is a function of the modularity and diagnostic capability of the electronics. Today's service technicians are trained to use computer tools to diagnose faults in preference to the old methods of oscilloscopes and analogue electronic expertise. Technicians with analogue electronics expertise are getting few and far between. Modern digital electronics with embedded intelligence almost always include the additional capability of being able to easily diagnose the source of faults, and their modularity allows for easy swap out.

Local Support

Aren't all these systems imported into Australia by agents?

It is true that much of the innovation in technology happens abroad, but that does not mean that you need to be dealing with ill-trained agents or distributors who have little investment in the success of these systems in Australia. There are Australian companies who have developed systems such as this suited to Australian market conditions. The Omniflex Poweterm range was designed to meet Australian conditions and is sold in Australia by Omniflex themselves. Omniflex Australia was incorporated in Australia ten years ago, and is part of the Omniflex international group of companies specialising in the design and manufacture of industrial electronic products and systems. Omniflex have local experts ready to provide support and training. Omniflex has a commitment to the success of the Powerterm product, and invest in training of selected system integrators around Australia to ensure that the equipment can be installed and commissioned optimally, and that first line local support is available where required.

Useability

Aren't these new systems complex to operate?

CP Systems are in the hands of structural and civil engineers. These engineers are trained to use computers as tools of the trade including the World Wide Web, and are more comfortable using a laptop than a electrical multimeter and clipboard. The elimination of manual recording also increases their efficiency, and assists in meeting the demand for traceable results.

The Available Benefits

Reduced Carbon Footprint

Two opportunities present themselves by using the latest available technology as described above:

- The efficiency of the T/R units can be increased, reducing the energy running costs by 30%
- By utilising better monitoring and control techniques, it is possible to better control the CP system so that only the required amount of current is impressed on to the structure to provide the cathodic protection.

Better Cathodic Protection

By utilising remote monitoring and control, the state of the system is constantly being monitored and any discrepancies can be immediately acted upon. This can significantly improve the ongoing quality of cathodic protection.

Reduced Operational Costs

A more significant saving than the energy reduction is the reduced number of site visits that can be achieved using remote monitoring and control of CP systems.

The following table shows the savings that remote monitoring and control can achieve in a range of CP system sizes:

(1. Auto=monitoring installed; Manual= no monitoring installed)

	Local (no travel time)				Remote (travel 2x0.5 days included)			
	Small System 3 Zone		Large System 20 Zone		Small System 3 Zone		Large System 20 Zone	
	Manual[1]	Auto[1]	Manual	Auto	Manual	Auto	Manual	Auto
Commissioning	1	1	2	2	2	1	3	2
After 1 month	1	0	1.5	0	2	0	2.5	0
After3 months	1	0	1.5	0	2	0	2.5	0
After 6 month	1	0	1.5	0	2	0	2.5	0
After 12 months	2	1	3	1.5	3	1	4	1.5
After 18 month	1	0	1	0	2	0	2	0
After 24 month	2	1	3	1.5	3	1	4	1.5
After 30 month	1	0	1	0	2	0	2	0
After 36 month	2	1	3	1.5	3	1	4	1.5
Total Days	12	4	17.5	6.5	21	4	26.5	6.5
Day Rate	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400
Site Cost	$16,800	$5,600	$24,500	$9,100	$29,400	$5,600	$37,100	$9,100
SAVINGS		**$11,200**		**$15,400**		**$23,800**		**$28,000**

Table 1: Comparison of Site Time and Cost for Typical CP Systems over 3 year period with and without remote monitoring installed.

Conclusion

By deploying the currently available 21st century electronic technologies to improve efficiency and implement remote monitoring and control, significant savings in operating costs can be achieved in cathodic protection systems.

Monitoring systems have been developed specifically for the Cathodic Protection industry, such as the Powerterm CP system from Omniflex, that meet the requirements of the harsh Australian conditions and are tailored to suit the operational requirements.

Options exist for local monitoring only, local logging, or full remote monitoring. Systems installed with local monitoring only can easily be upgraded to remote monitoring at a later date.

These systems are capable and reliable and implementation risks are low.