Cathodic Protection for Above Ground Storage Tank Bottom Using Data Acquisition

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Abstract

Impressed current cathodic protection controlled by computer gives the ideal solution to the changes in environmental factors and long term coating degradation. The protection potential distribution achieved and the current demand on the anode can be regulated to protection criteria, to achieve the effective protection for the system.

In this paper, cathodic protection problem of above ground steel storage tank was investigated by an impressed current of cathodic protection with controlled potential of electrical system to manage the variation in soil resistivity. Corrosion controller has been implemented for above ground tank in LABVIEW where tank's bottom potential to soil was manipulated to the desired set point (protection criterion 850 mV). National Instruments Data Acquisition (NI-DAQ) and PC controllers for tank corrosion control system provides quick response to achieve steady state condition for any kind of disturbances.

Key words: cathodic protection; impressed current; above ground tank bottom; control; DAQ.

السيطرة على الحماية الكاثودية لقاعدة الخزان فوق الارض باستخدام بطاقة تبادل البيانات

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الخلاصة

تقدم السيطرة بواسطة الحاسوب على نظام الحماية الكاثودية ذات التيار القسري حلا مثاليا للمتغيرات المؤثرة منها العوامل البيئية مثل الرطوبة وتدهور طلاء المعدن على المدى الطويل ولتحقيق توزيع جهد الحماية الكاثودية من خلال تنظيم التيار اللازم على الأنود للوصول الى حدود الحماية الفعالة للنظام.

في هذا البحث، درست الحماية الكاثودية لقاعدة الخزان من الحديد الصلب فوق سطح الأرض من خلال تسليط تيار الحماية الكاثودية مع إمكانية التحكم في التيار الكهربائي الواصل الى قطب الانود لمعالجة الفرق الحاصل بالجهد نتيجة التغيير في قيمة مقاومة التربة الكهربائية والتي تتأثر بالرطوبة، تم التحكم على تآكل الخزانات فوق الأرض بواسطة نظام الـ LABVIEWوذلك من خلال تغيير الجهد الواصل عبر التربة الى قاعدة الخزان السفلية إلى نقطة مختارة سلفا 850 ملي فولت.

منظومة السيطرة على التآكل المتالفة من حاسوب ووحدة التحكم NI-DAQ لحماية الخزان توفر استجابة سريعة لتحقيق حالة الاستقرار بالجهد اللازم للحماية لأي نوع من الاضطرابات.

الكلمات الرئيسية: حماية كاثودية، تيار قسري، قاعدة خزان فوق سطح الارض، سيطرة، بطاقة تحصيل البيانات.

1. INTRODUCTION

Storage facilities for petroleum products usually consist of a collection of above ground storage tanks called a tank farm. The tanks are cylindrical in shape, constructed of steel, and rest on the soil. The tank bottom, then, is subject to the same corrosion issues as are buried pipelines. The provision of cathodic protection to tank bottoms is, if anything, more critical than is provision of cathodic protection to pipelines. As the tank bottom is supported by the ground and is subjected to only hydrostatic pressures, the bottom can be made of thinner metal than is used for pipelines, which operate under pressure. Because the metal is thinner, it can be more easily perforated by even low rates of corrosion. The provision of cathodic protection to the bottoms of above-ground storage tanks for petroleum products, however, presents unique design issues as compared to pipelines, **Riemer , et al., 2005.**

Corrosion occurs in aqueous (water-containing) environments and is electrochemical in nature. The aqueous environment is also referred to as the electrolyte and, in the case of underground corrosion, is moist soil. The corrosion process involves the removal of electrons (oxidation) of the metal, **Peabody, 2001.**

It is well known that all metallic structures buried or immersed, and even concreted, inevitably undergo the phenomenon of corrosion once plunged in an electrolyte. Cathodic protection (*CP*), after a good passive protection, is an efficient means of stopping the process of corrosion. It lowers the potential of the protected metallic structure to the value where the reaction of corrosion cannot take place; this potential is known as "threshold of immunity" **,Jain A. K et al., 2011** and **Javadi, et al., 2014.**

External cathodic protection systems are applicable to tanks of any size where the soil corrosivity is sufficient to reduce the tank bottom life to an unacceptably short period. One of the key indicators of corrosivity is the soil resistance. Soil resistivity is used not only to evaluate corrosivity, but also to design the anode ground bed **,Philip, 2009.**

In most cases, it requires energy from an electrical energy source to impress the current. This power to provide the needed current to prevent corrosion with appropriate potential that change due environmental conditions. For this purpose, a lot of experimental work has been done. In this case, a regulated power supply derived by electronic circuit signal from *DAQ* powered cathodic protection system has been designed. The developed circuit allows potentials to be all the time at desired (proper) limits 0.85-0.9V [If a tank has a potential of -850 mV with respect to the copper/copper-sulfate cell then it is usually considered protected. [Protection Criterion The well-known protection criterion for steel in soils of -850 mV with respect to a saturated copper/copper sulfate reference electrode *CSE* was reportedly pioneered by **,Robert**, dating back to **1933**.

When the soil resistivity changes, PC software takes care of this and changing the voltages thru manipulating *DAQ* analog output to anode keep the potential 0.85 V - 1.10V. On the other hand, to stop corrosion entirely, in recent years, there has been increasing interest in the development of efficient corrosion control to improve *CP*. Thus, several control circuits intended to regulate *ICCP* have been designed and discussed **,Kharzi, et al., 2009.**

In this work, to overcome this difficulty, an automatically regulated cathodic protection system with *DAQ* control is proposed. This system senses the variations of the surrounding medium resistivity by measuring the impressed voltage E_i of the bottom of the tank branch against a buried reference electrode $Cu/CuSO_4$ (*CSE*) and adjusts automatically the (*DC*) output voltage of the adapter circuit so that the current is kept nearly constant at the required level regardless of the soil resistivity variations. This system is developed around the *PC–NI DAQ* which controls the output voltage of the anode, the charging voltage from Power supply **Fig. 1**. The acquisition of the different parameters, as well as the measure of the impressed voltage against the buried reference electrode *CSE*, is allowed by the *DAQ* ports. By using this suggested system, two important goals are achieved. The first one is the prevention of corrosion, because the metallic structure will always receive the exact current required for protection. The second goal is the reduction of maintenance costs and system costs by using high-efficiency power conditioners.

In this study an optimized cathodic protection system has been developed for tuning output voltage of the interface adapter to keep the current of protection (impressed current) nearly constant in order to reach the protection criterion. On the other hand, the cost powered system is improved by the efficient use of its generated electric power by way of the maximum power.

2. SYSTEM DESCRIPTION

Storage tank bottoms of steel structure subject to transitional environments due to changes in soil type (moisture content). Changes simulates the height of the water table or season rains, for example, will affect not only the availability of water but also the access of oxygen to the protected structure surface *PSS*. Transitions between different soil types will also result in different exposure conditions for different parts of the *PSS*. These variations can affect the value of potential on the tank bottoms surface and the ability of the cathodic protection *CP* system to provide adequate protection. A combination of different soil in laboratory and field measurements on operating conditions bottom vessel (1 m diameter) has been used to study the effect of varying moisture content and water level on the level of cathodic protection for tank bottoms subjected to environmental conditions. In both laboratory tests and field trials, the degree of protection was found to depend on the availability of cathodic reactants (O_2 and/or H_2O), **,Philip, 2009.**

Tank to soil potential under protection is measured using $Cu/CuSO_4$ (*CSE*). It is fed as input signal to analog input module of the Data Acquisition Card (*DAQ*) [NI 6009]. Desired set point 0.85 V (normally between -0.85 to -1.1 Volts) is entered manually. Controller module gives output based on the set point (*SP*). This controller operates in direct acting mode (increase in error increases the controller output) **Fig. 1**.

Controller module output is assigned to analog output module of *DAQ*. Output of the controller dynamically varies the triggering base of transistor. Single phase AC power supply is fed to the transistor. Step down transformer (220/30 Volts) *positive terminal* is connected as load to the transistor collector [regulated power supply] and emitter feed the anode (30 cm long, 5 cm in diameter) of high cast iron silicon which is buried 0.5 m (center) down the bottom of the tank and the *negative terminal* to tank body, **Fig. 2**.

By using computer to control corrosion thru software and modeling program built in LABVIEW Fig. 3 to maximize the effectiveness of impressed current cathodic protection *ICCP*. Computer modeling provides the tools to predict how a particular system will perform even for the most complex situations. It can provide quantitative information on the protection potentials achieved and the life of the system, thus reducing the risk of systems not meeting the design goals and enabling future management of assets to be planned effectively.
Virtual Instrumentation controller front panel is presented in **Fig. 3**. Over protection window will become red in color when tank to soil potential *(TSP)* is greater than -1.0 Volts, under protection window will become red if the *TSP* is less than -0.85 Volts. When the controller is set in *without control* mode, set point will directly go as output. In manual mode if the *set point* is 0.85 then *controller output* will also be 0.85 Volts. Under the *Auto TSP* mode, it will try to maintain the *TSP* as per the *Set Point*.
Block diagram (program written in LABVIEW), inputs (error and change in error) are used and one single output (controller output) is used. For corrosion control purpose, *TSP* is used as process value. Here formula blocks are used to convert the sign. In this design, *TSP*, controller output voltage and controller output current are measured through *DAQ* input channels controller output is sent through *DAQ* output channel.

3. RESULTS AND DISCUSSIONS

One of the main conditions to be satisfied by an *ICCP* system is that the protected structure is to be fed by a constant current determined by the structure's metal, the area, and the surrounding medium. However, due to the environmental conditions, *CP* resistance changes significantly due to the anode-to-earth resistance being affected by the variations of the surrounding medium resistivity accordingly to extreme dry-to-wet conditions, which leads to the variation of the output current (impressed current).
Sandy soils taken to study electrical soil resistivity changes with wide range of moisture content, these experiments were taken using four points method **Fig. 4**.

Soil resistivity is an electrical characteristic of the soil/groundwater which affects the ability of corrosion currents to flow through the electrolyte (soil/groundwater).

Resistivity is a function of soil moisture and the concentrations of ionic soluble salts and is considered to be most comprehensive indicator of a soil’s corrosivity. Typically, the lower the resistivity, the higher will be the corrosivity of variation.
Starting the experiments with initial conditions of electrical soil resistant equal to 1400 ohm cm at 30% water content under the bottom of the tank, calculating the current and voltage required to achieve tank to soil potential -880 mV which means the structure are protected.

By changing in moisture of soil by adding water (therefore soil resistivity decreases to ≈ 1000 ohm cm) **Fig. 6** followed in disturbance with tank to soil potential **Fig. 7** potential, this drives the *DAQ* to compensate the difference in protected potential thru program built in LABVIEW Fig. 3 to reach the acceptable soil potential (the controlled variable) measured thru CSE copper/copper sulfate electrode by manipulating anode voltage fed form regulated power supply derived by *DAQ*.
Response of the controller is shown in **Fig. 7**. Initially electrolyte conductivity is varied by adding water and controller performance is observed. Controller brought the process value (*TSP*) towards the set point 850 mV. Variation in soil resistance affects corrosion process which, accelerates corrosion by access of O_2 results in a positive shift in potential as more current is

required to electrochemically reduce the oxidant and the tank bottoms is less easily polarized. Under some circumstances, the access of water has the same effect. Although more aerobic conditions lead to more positive potentials, the tank bottoms is not necessarily less well protected. In many dry and/or high resistivity soils, the tank bottoms surface may well be passive because of the high interfacial pH and/or high O_2 concentration **,Fraser , 2011.** In both cases the controller is taking corrective action and bringing process value towards set point.
Fig. 7 also shows response time takes about 2 min which is practically acceptable, many experiments taken (decreasing moisture/increasing electrical soil resistivity) the results approximately agree with the limits of period time.

4. CONCLUSIONS

In this work, a controller for the cathodic protection for above ground tank, has been developed, implemented and evaluated. The model is based on a *PC DAQ* controller were written by LabView. The following conclusions may be drawn from constructing and testing this system;

1. The close control protects the bottom tank from the corrosion. The controller was flexible, and the model corresponded well with the changing of the soil resistivity (the current always try to keep the voltage on the tank base at the set point with 850 mV under protected at some points to 1000 mV under over protected at other points. This is with the acceptable range.
2. *PC* controllers for tank corrosion control system because of quick response to achieve steady state condition for any kind of disturbances, it is very flexible and easy to operate. Design and development of virtual instrumentation Corrosion controller has been implemented for above ground tank. It prevents the tank corrosion by precisely controlling the tank to soil potential at the desired level, conventional *PID* and without controller, better time domain response is obtained about 2 min.
3. In the conventional controllers, operator intervention is more and during start up to be kept in without controller with tank to soil potential reversely increases with soil resistivity for time duration of around 1.5 min occurs over/under protection before putting in the with controller mode.
4. *PC DAQ* requirements can be successfully reduced. Hence, significant cost savings are achievable.
5. New controller is designed so that, to take minimum power to *ICCP*, therefore the overall efficiency of the system is improved significantly. Moreover, a new circuit model is proposed for underground tank bottoms lines and can be used in the simulation of cathodic protection systems. In simulation, the worst conditions have been considered to increase the lifetime of the system and to cause the designed system to be useful in different climatic condition.
6. There are no restrictions to apply this control protection system for different structure geometry, and can be used for the case of structure in offshore, subsea or onshore including shallow coastal waters. Materials include steel - coated or uncoated; other metals; reinforced concrete and hybrid structures. *CP* system will perform over time so that can improve the timing and optimum of *ICCP*.

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Abbreviations

AC	Alternating Current
CP	Cathodic protection
CSE	Copper/copper Sulfate reference electrode
DAQ	Data Acquisition
DC	Direct Current
ICCP	Impressed Current Cathodic Protection
NI	National Instruments
PC	Personal Computer
PID	Proportional Integral Derivative controller
PSS.	Protected Structure Surface
SP	Set Point
TSP	Tank to Soil Potential

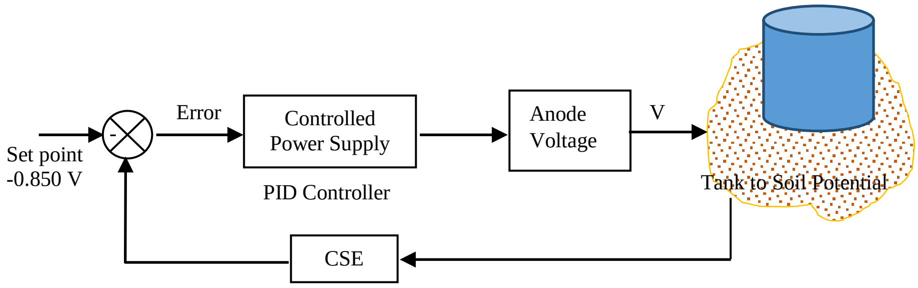

Figure 1. Close loop control for tank to soil potential.

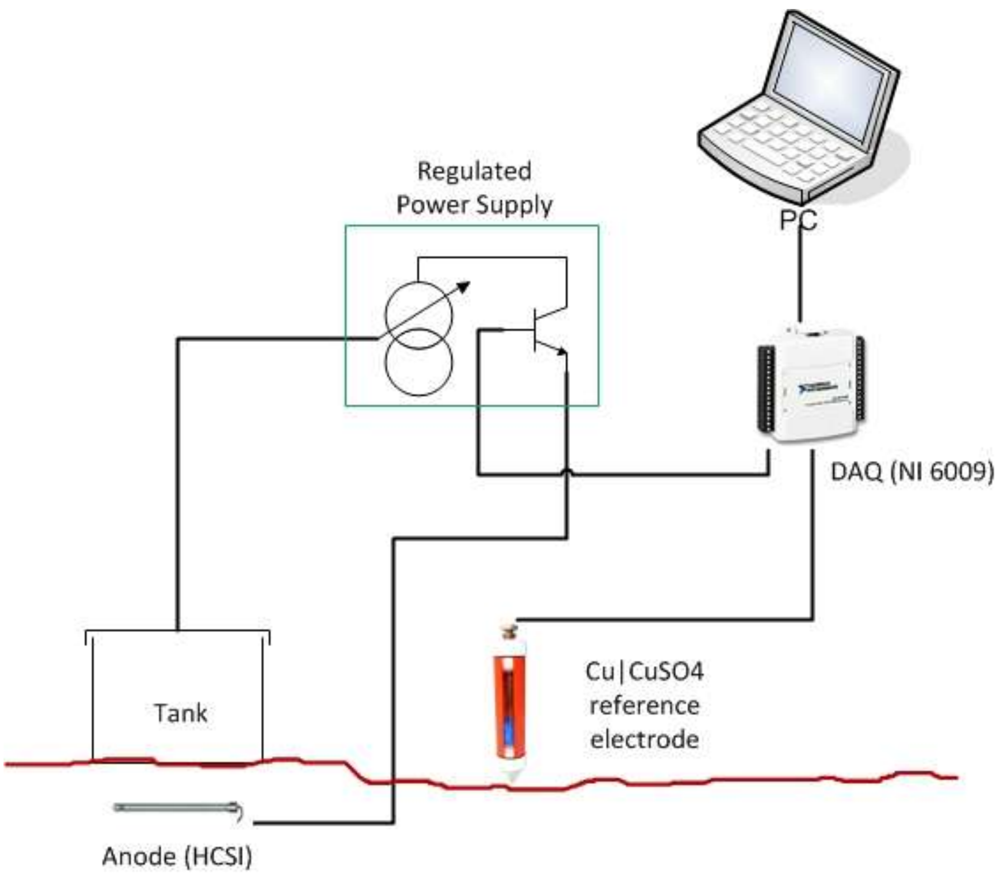

Figure 2. Schematic diagram for tank ICCP.

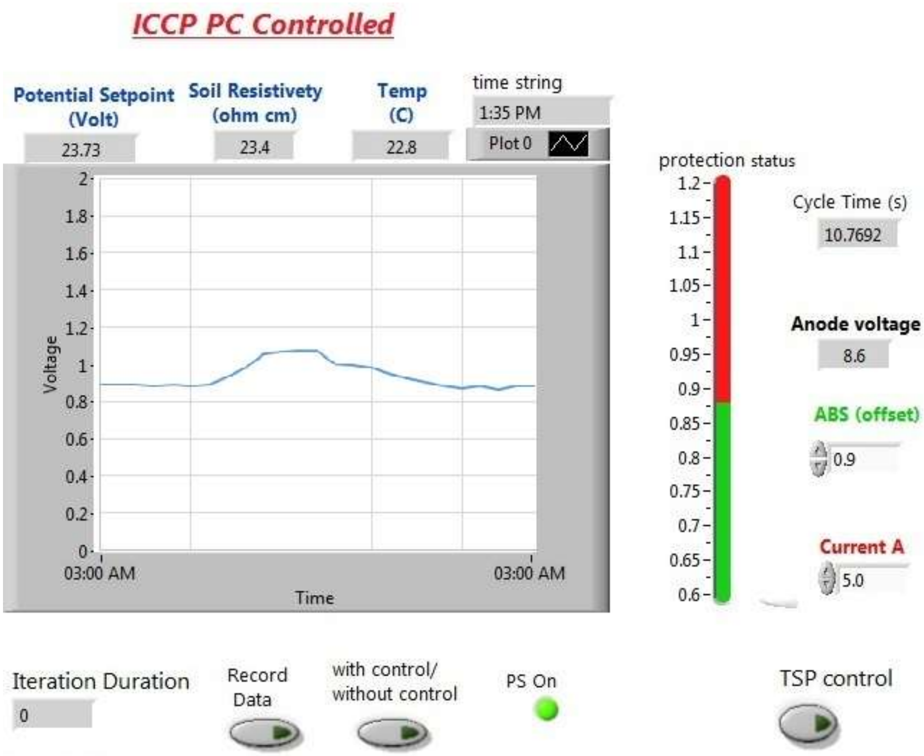

Figure 3. Front panel of impressed currents cathodic protection controller.

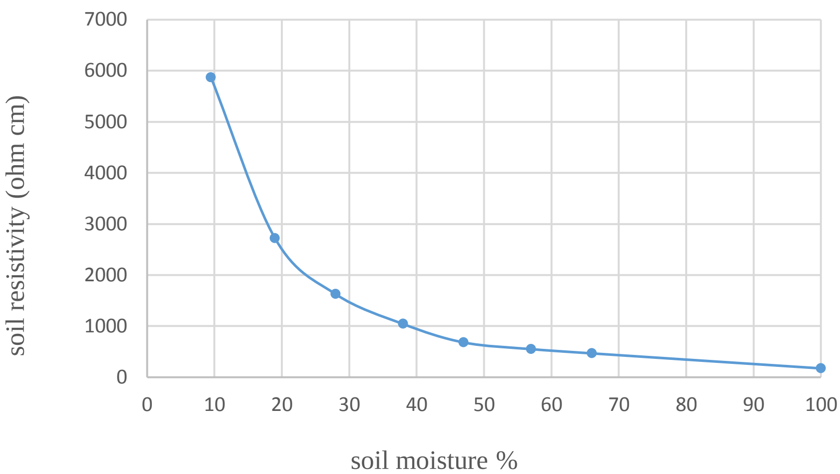

Figure 4. Soil resistivity vs. soil moisture.

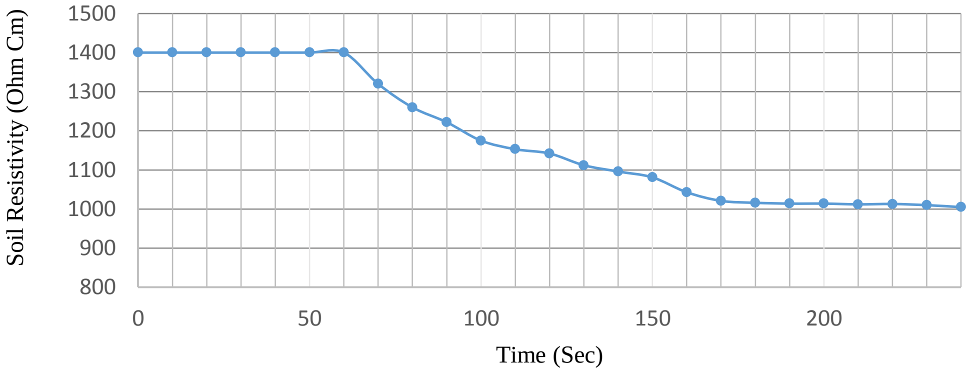

Figure 5. Soil resistivity change vs. time.

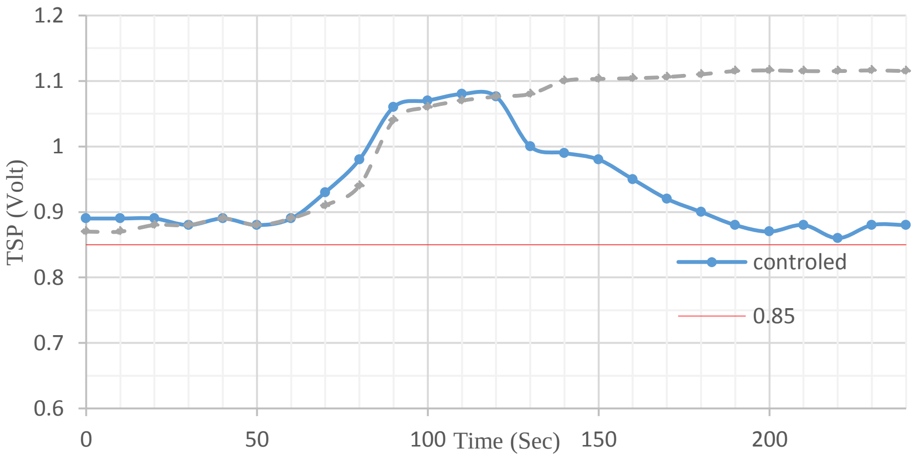

Figure 6. Tank to soil potential vs. time.

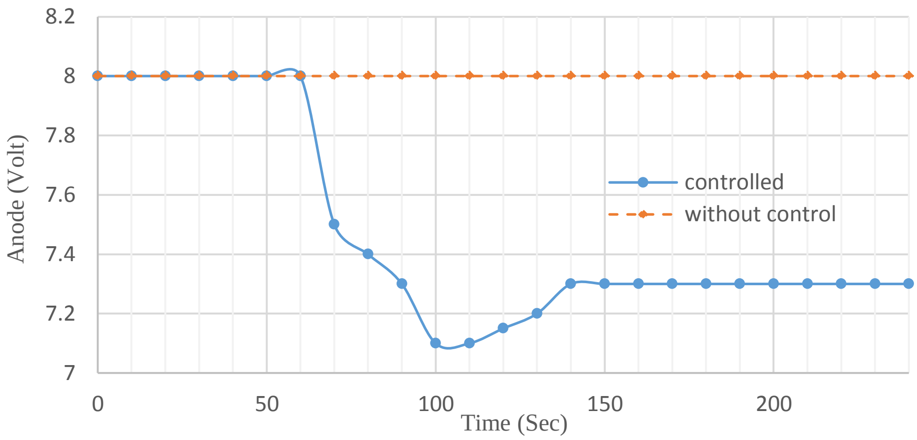

Figure 7. Supplied voltage to anode vs. time.