RIIO-T2 Re-opener
St Fergus Terminal Cathodic Protection

Engineering Justification Paper

January 2023

nationalgrid

Contents

1. Executive Summary

1.1. National Grid Gas Transmission, (hereafter referred to as 'NGGT'), are submitting the needs case in accordance with the RIIO-T2 Engineering Justification Paper Guidance v2 document. The purpose of this stage of the process is to provide Ofgem with additional information that justifies the project need case, setting out the different options considered and the preferred strategic option. This Engineering Justification Paper (EJP) details the investment required by the preferred strategic option associated with the Cathodic Protection (CP) system at St Fergus Terminal.

1.2. The current site CP system was originally installed at the time of terminal construction in 1974 and has been operated constantly since then to provide the necessary protection to the buried pipework on site. Over the years there have been developments such as replacement of ground beds and additional loads as the result of pipework and asset modifications as the result of project work. CP Systems typically act as a secondary form of protection against corrosion, with the primary defence being the pipeline coating. However, due to the age, evidence of coating deterioration and increased load requirements, the importance of the CP system in maintaining the integrity of the buried pipework is increased. Surveys have found that only 37% of the test posts at St Fergus showed a satisfactory reading in the specified protection range.

1.3. This is part of a suite of documents, shown in Figure 1, and should particularly be read in conjunction with the St Fergus Site Strategy and its appendices.

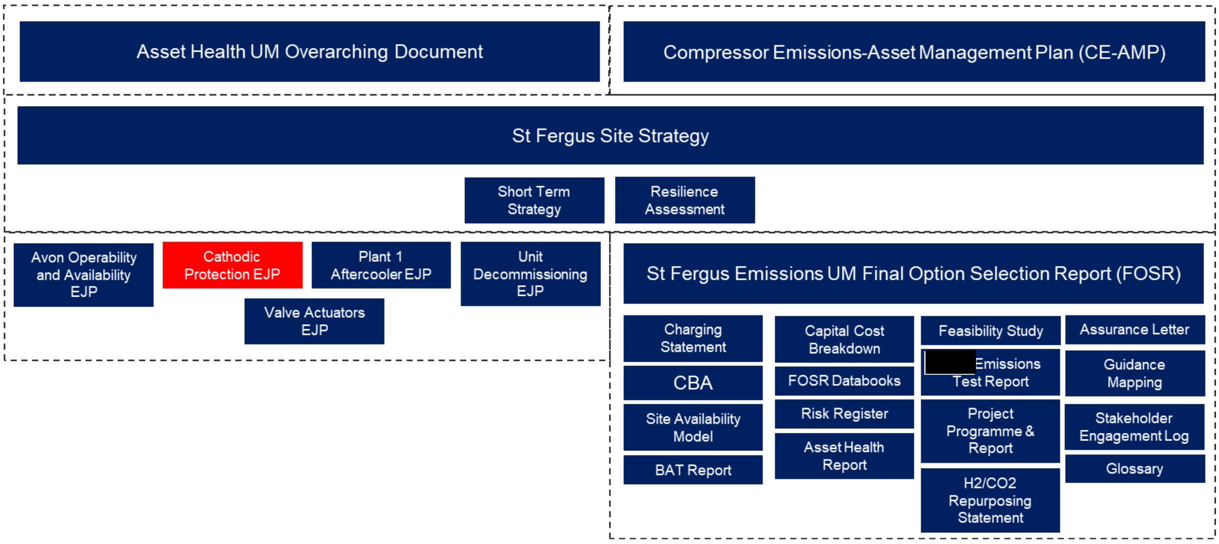

Figure 1 – St Fergus Submission Documents Structure

1.4. Our St Fergus Short-Term Strategy[1] provides certainty on the terminal operation requirements, out to 2030. The long-term strategy will deliver the enduring terminal solution, including gas compression, required for operation beyond 2030. This investment is aligned with both strategies as a functioning CP System is required across the terminal, regardless of its future configuration.

1.5. As a result, a range of options were considered and assessed:

- Do Nothing
- Rehabilitate of part replacement of CP system
- Remedial coating repairs to remove localised current drain defects
- Replace CP system

[1] See Appendix 1

1.6. The recommended option for the replacement of the CP system is option 4, wholesale replacement. This delivers the most economic and efficient option for the site to achieve both its short and long-term strategy needs and is driven by compliance, associated risk and cost.

1.7. Replacement of the CP System at St Fergus Terminal was included within the RIIO-T2 Business Plan as part of the Plant & Equipment section of Asset Health, with some baseline funding provided ahead of the Asset Health Re-opener defined by Special Condition 3.14. The current estimated total cost of this investment is [redacted] (2018/19 price base) – excluding baseline funding of [redacted]. This project is at stage 4.4 in the ND500 process: Detailed Design and Delivery. Therefore, the cost accuracy is estimated at +/-10% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

£m 18/19	Prior Years	FY2022	FY2023	FY2024	FY2025	FY2026	Total
Total Cost	[redacted]						
Baseline							
Funding Requested							

Table 1 – Current estimated RIIO-T2 spend profile

1.8. This work is being delivered via a competitive call off the NGGT Asset Health framework and is bundled with the corrosion remediation at St Fergus to drive efficiency. Cathodic Protection, corrosion remediation works and actuator works are bundled on site for delivery, to maximise the work completed as part of each isolation at St Fergus. These works were identified as part of our RIIO-T2 business plan following discussions with the HSE and subsequent studies and therefore have commenced due to the importance of ensuring site pipework is adequately protected in light of its aging pipework coating and the deterioration of protection following survey.

1.9. We are making this funding application for the Cathodic Protection Programme RIIO-T2 investment costs through the Asset Health Re-opener, in line with Special Condition 3.14, requesting an adjustment to the value of the NARMAHOt term. This is summarised, along with other investments, within section 9 of the Asset Health Overarching Document provided as Product 1 of the January 2023 Asset Health Re-opener Submission. A draft of this paper was shared with Ofgem prior to this submission.

2. Introduction and Background

2.1 This paper provides the justification for the replacement of the Cathodic Protection (CP) system at the St Fergus gas terminal. This draft is being submitted ahead of the Asset Health Re-opener submission date set for January 2023.

2.2 The St Fergus Gas Terminal contains approximately 19km of buried pipework, which is coated as a primary means of corrosion prevention and protected by Cathodic Protection as a secondary means. The existing CP system, installed at the time of construction, is now over 40 years old and is no longer providing adequate protection to the buried pipework.

2.3 The current primary protection system, the coating, has started to deteriorate. This is evidenced by the increase in current load for the CP system as well as through excavations completed to support a remnant life study which was carried out. This increases the importance of a functioning CP system to manage the integrity of the pipework.

2.4 The CP system is one large integrated unit; however, the terminal is broadly divided into four sections for ease of reference, namely: Plant 1, Plant 2, Plant 4 and South AGI. The terminal was commissioned in 1977 and was inaugurated by HM The Queen 9th May 1978.

2.5 In developing our investment programmes at the St Fergus gas terminal since the RIIO-T2 Final Determinations, we have adopted a two-phase strategy to ensure clarity between short-term asset health and long-term site operating strategy. Our St Fergus short-term strategy provides certainty on the terminal operation requirements, including minimum compression across Plant 1 and 2, for operation out to 2030. The long-term strategy will deliver the enduring terminal solution, including gas compression, required for operation beyond 2030. The CP system is used to protect the site's below ground pipework that connects all the assets on site and will be needed for as long as the site continues to transport gas. The design proposed follows best practice by incorporating appropriate allowance for the system to last and adapt to future developments ensuring minimal investment would be required to accommodate the long-term solution.

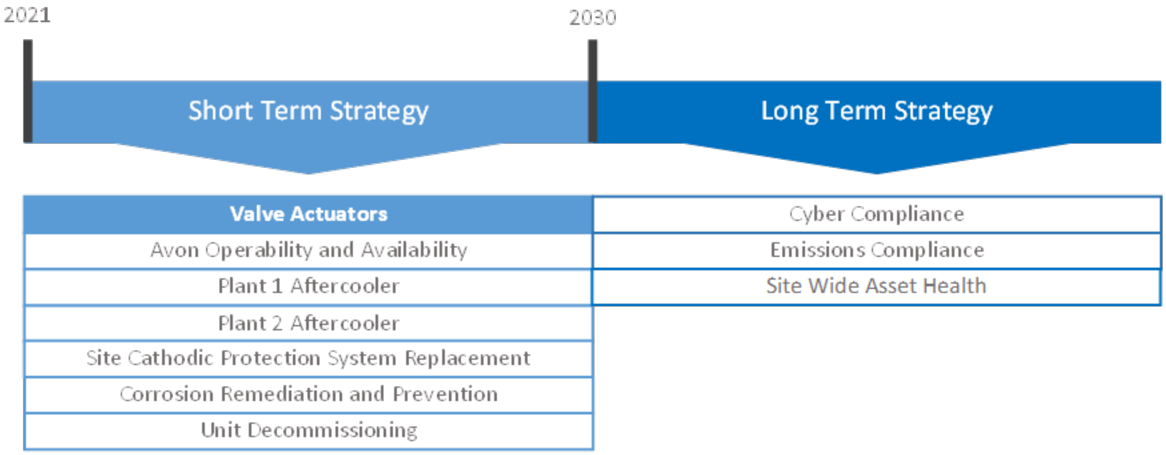

Figure 2 – St Fergus Strategies Summary

2.6 Due to age, evidence of coating deterioration and increased load requirements, the importance of a fully functioning CP system in maintaining the integrity of the buried pipework is increased. It must be fit for purpose to cover both our short and long-term strategies.

2.7 St Fergus is a facility governed under the Control of Major Accident Hazards (COMAH) Regulations 2015 and falls within the top tier COMAH site distinction. As such, it is subject to numerous requirements to demonstrate that safety and environmental risks from and within the facility are understood and being managed to a level to be shown to be 'As Low as Reasonably Practicable (ALARP)' taking 'All Measures Necessary' to manage such risks. Also, the Pressure Systems Safety Regulations 2000 (PSSR), apply to the site pipework.

2.8 The original 1970's design of cathodic protection systems on site does not provide any redundancy to a failure of any part of the system, which means that the system is in constant use.

2.9 The current site CP system was installed at the time of terminal construction in 1974 and has been operated constantly since then to provide the necessary protection to the buried pipework on site. In the intervening years, Variable Speed Drive (VSD) compressors have been added, amongst other plant and equipment. All these changes and the general complexity of the St Fergus terminal impact the efficacy of the CP system.

2.10 Work to deliver the replacement cathodic protection system could not wait until the re-opener date provided by Ofgem in the RIIO-T2 Final Determinations. An ALARP study and subsequent remnant life study have highlighted that the risk to small bore pipework on site was not ALARP. As a prudent operator, NGGT has initiated work and this justification paper is now retrospective in nature.

2.11 The site cathodic protection is classed as a complex structure as defined within BS EN 14505 [9]: Cathodic Protection of Complex Structures as "a structure composed of the structure to be protected and of one or more foreign electrodes, which, for safety or technical reasons, cannot be electrically separated from it."

2.12 In the case of St Fergus, this includes the following:

a) Shielding of flow of the cathodic protection current by reinforced concrete foundations, pits, culverts, etc.

b) Electrical isolation of piping made ineffective by electrical earthing systems, etc.

c) Interaction with other buried metallic structures and assets.

3. Equipment Summary

Site Overview

3.1 Comprehensive background information about the St Fergus Gas Terminal is available in the St Fergus Site Strategy provided with the Emissions Final Option Selection Report (FOSR).

3.2 A total of approximately 19km (33,000m2) of coated, buried steel has been identified and scaled from the available layout drawings. An illustration of the complexity of the station pipework is shown below but does not include the small-bore pipework (below 300mm).

[redacted]

Figure 3 – St Fergus Terminal pipework

3.3 Approximately 500m of the pipework on site is stainless steel. These stainless-steel lines transport glycol to and from the Variable Speed Drive (VSD) compressors.

Type of Pipework	Approximate Length (m)
Small bore buried vent piping (average 200 mm dia)	9500 m
Buried gas piping (average 900mm dia)	9700 m

Table 2 – Approximate Lengths of Buried Steel Pipework

The Role of Cathodic Protection

3.4 Buried pipework will corrode, therefore other assets are in place to manage and mitigate this. The main time-dependent threat, to adversely affect buried pipework's technical life, is external corrosion. Pipeline Coating applied to the outside surface of the pipeline is the primary corrosion protection for all pipework. Various coating methods are in use depending upon the location and age of the pipeline.

3.5 The coating of a pipeline is the first line of defence from external corrosion which is critical to minimise the likelihood of interruptions to the distribution of gas. However, no coating is flawless. Therefore, CP is an effective complementary method to protect structures in a corrosive environment which is a recognised industry practice. Coatings are designed with a 40-year life and deteriorate with age, with each type having different rates and characteristics and presenting different issues for resolution. This results in an increasing reliance on the CP system to compensate and mitigate corrosion.

The Cathodic Protection System at St Fergus

3.6 CP is installed on all pipework at St. Fergus as secondary protection to prevent corrosion where the coating has failed. The key elements of the impressed current CP systems are the transformer rectifier, ground bed, CP test post and remote monitors.

Figure 4 – Example Cathodic Protection Test Post and Transformer Rectifier Cabinet

3.7 The existing plant Impressed Current system was installed in 1974, which comprises four conventional Transformer Rectifiers Units (TRUs). The TRUs are located at the following locations.

- Cathodic Protection Station South A.G.I. (25A/25V)
- Cathodic Protection Station PCB1 Plant 1 (50A/50V)
- Cathodic Protection Station PCB2 Plant 2 (50A/50V)
- Cathodic Protection Station DB4 Building (25A/25V)

3.8 There is a distributed CP system present and the existing groundbeds on site are mostly shallow. Each groundbed is comprised of single/double silicon iron anodes, many of which are connected to anode junction boxes leading to the TRUs. Approximately 200 groundbeds are present on site. The performance of the CP system is monitored using over 100 potential monitoring test points in addition to coupon junction boxes that are installed at several locations across the terminal.

3.9 The current site CP system was installed at the time of terminal construction in 1974 and has been operated constantly since then to provide the necessary protection to the buried pipework on site. In the intervening years, Variable Speed Drive compressors have been added, amongst other plant and equipment. All these changes and the general complexity of the St Fergus terminal impact the efficacy of the CP system.

3.10 CP Systems typically act as a secondary form of protection against corrosion, with the primary defence being the pipeline coating. At the point when the primary coating system fails, the CP system becomes the primary system to prevent corrosion occurring. Due to the age, evidence of coating deterioration and increased load, the importance of the CP system in maintaining the integrity of the buried pipework is increased.

4. Problem Statement and Need Case

4.1 The CP system at St Fergus will require investment during RIIO-T2 to manage its performance in the medium and long term, ensuring its continued fitness for purpose under the PSSR. Failures of pipelines would directly impact the security of supply for our customers and the safety of everyone in proximity to our buried assets.

4.2 It is more cost beneficial to address the protection systems than to allow the pipeline to deteriorate to a point where it requires significant remediation or replacement. Detecting such deterioration is a significant challenge as there are no standard techniques that we can apply at St Fergus which provides information on where metal loss has occurred and what the extent of that loss might be. One exception is our innovative Gas Robotic Agile Inspection Device (GRAID) which was designed specifically to inspect buried site pipework. However, this would only work for a fraction of the buried pipework at St Fergus. Therefore, given the cost of a standard dig [redacted] the complexity of this site and the additional depth (around 6m deep), inspection would have a significantly higher cost.

4.3 The intolerability of the risk is uncovered when the relatively modern principals of whole life asset management and Reliability, Availability, and Maintainability (RAM) optimisation are applied and particularly then considering the requirements under the COMAH regulations. The intervention and continuing scrutiny from the HSE in connection with the gradual failure of the CP system, highlights the severity of the situation.

4.4 The primary reason for the progressive failure of the system is due to the deterioration of the impressed current ground beds which have come to the end of their design life, such that they are no longer able to provide the current required for full protection of the below ground pipework. The secondary reason is due to the gradual degradation of the external coating systems resulting in a greater current density requirement. As coatings are past their design life, they will increasingly absorb moisture which results in a greater current demand in order to protect them thus further impacting the CP system.

4.5 A below ground leak on a section of small-bore pipeline was the result of corrosion on a two-inch pipe that went through a concrete deck. This pipe was cathodically shielded due to the presence of soft fill. Soft fill is a high dielectric strength material which does not permit CP current flow and is used on sites to reduce pipe stress. This incident resulted in two compressors being taken offline and is indicative of what would be considered a worst-case scenario with the pipework section unlikely to have ever received effective cathodic protection due to the design flaw, meaning that corrosion could continue unabated once a holiday (a discontinuity in coating) occurred in the primary coating system.

4.6 From excavations conducted following the remnant life study, it is clear that areas of coating are life expired which means that at this point the CP system should act as the primary protection method to ensure appropriate risk management. As part of the investigation, soft fill was found to be present in large quantities which means there may be other pipework which may be cathodically shielded on site. As the CP system has gradually become less effective and coating has deteriorated, previously protected pipework will also have faced an increasing risk of corrosion. The impact of any corrosion depends upon its location and also the ability to apply isolations to ensure continued gas flow through the site and compression facilities.

4.7 The integrity of the CP system and therefore the site pipework is the main factor for investment, particularly as the system becomes increasingly important in preventing corrosion as pipeline coatings age. Although corrosion can be addressed, we cannot fundamentally replace the lost metal and therefore prevention is essential to minimise the degradation of pipework which in many areas is reaching or has exceeded its design life. However, RAM issues (specifically the risk of single point failure of a pipeline causing catastrophic outage) and the difficulty in configuring isolations to facilitate inspection and repair of the plant, are compelling drivers for replacement of the CP system.

4.8 Data from a CP survey in 2019 indicated the level of protection distribution across the site, shown in Table 3. This is based upon a total of 40 amps output from the four Transformer Rectifier Units (TRUs) out of an installed 150 amps from the TRUs located at the South of the AGI, Plant 1 (PCB1), Plant 2 (PCB2) and Plant 4 (ECB4). This survey found that only 37% of the test posts at St Fergus showed a satisfactory reading.

Protection Level for Carbon Steel	Potential Range	% Pipework	Impact
Under Protected	More positive than -850mV OFF	49	Under protection will allow corrosion to take place at coating holidays due to insufficient CP current on the structure no longer polarising the steel to protected levels sufficient enough to prevent corrosion from occurring. Where interference is also present, and where the structure is unprotected, metal loss can be accelerated where current is discharged from unprotected coating defects. The metal loss is proportionate to the magnitude of current discharge, subject to under protection, and to the environment it is in such as soil resistivity.
Protected	-850mV to -1150mV OFF	37	
Over Protected	More negative than -1150mV OFF	14	Over protection causes coating disbondment (cathodic shielding) and can damage the coating in general. This then reduces the effectiveness of the coating this requiring ever more current to achieve protection. Over-polarisation also causes osmotic blistering and results in premature aging and failure of the coating thereby requiring additional current to be distributed to such areas or physical interventions to be made to repair or replace the existing coating.

Table 3 – Carbon Steel Protection Percentage

4.9 A further challenge is presented by the approximately 500m of buried stainless steel on the site. This is associated with the glycol pipelines which form part of the electrically driven compressor assembly. The protection criteria for buried stainless steel differs markedly from carbon steel. The protection ranges for stainless steel are shown in Table 4 and a comparison to those for carbon steel is shown in Figure 5.

Protection Level for Stainless Steel	Potential Range
Under Protected	More positive than -650mV OFF
Protected	-650mV to -900mV OFF
Over Protected	More negative than -900mV OFF

Table 4 – Stainless Steel Protection Ranges

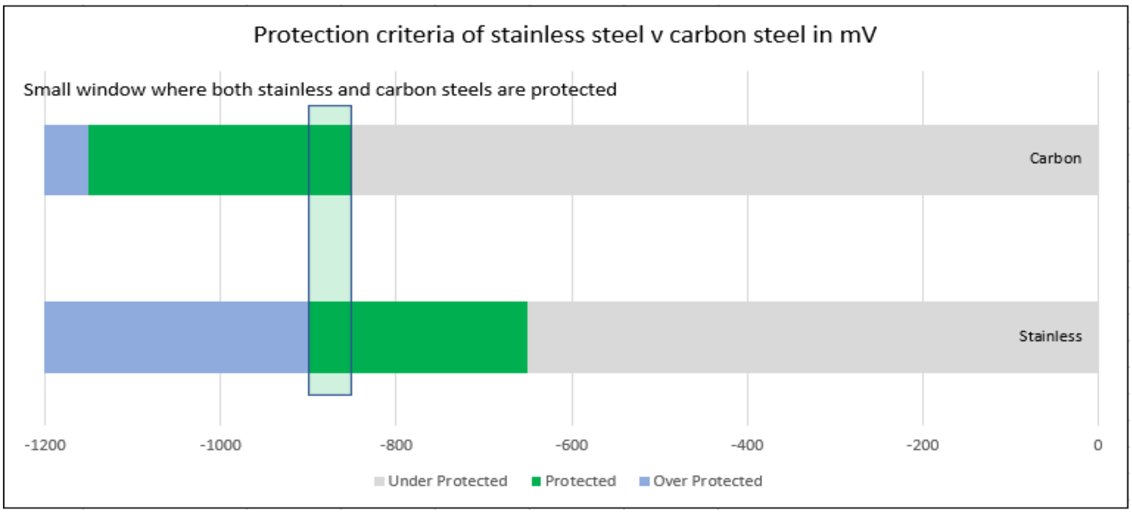

Figure 5 – Protection Criteria for Stainless Steel and Carbon Steel

4.10 At St Fergus, the stainless steel is electrically common with the carbon steel through the electric drives. Therefore, managing local current distribution is particularly challenging as the minimum protected polarised potential for carbon steel is close to the over polarisation limits for stainless leaving only a small window where both are protected. A new CP system could be designed which would be managed by zone, with individual control to each anode junction box within each zone. So that adjustment could be made locally in the zone where stainless is receiving current.

4.11 Reports have shown:

- South AGI TRU is non-functional, has a high ground bed resistance (38V/1amp), and 82% failed to meet the –850mV OFF potential criterion as per T/PM/ECP/2.
- 56% of the readings in Plant 1 did not meet the -850 vs CSE criterion with the TRU output reading 3.5A/17V. It should be noted that a fair portion of piping in the Plant 1 compressor area is under concrete which may have affected the reported readings, either as current drain through rebars or piping installed inside ducts with no earth contact. Effective CP in this area will therefore be difficult to achieve and will require additional ground beds compared to other areas of the site.
- 49% of the readings in Plant 2 did not meet the -850 vs CSE criterion, with the TRU output reading 14A/24V. It should be noted that compressor area piping is under concrete which may have affected the reported readings.

- 29% of the readings in Plant 4 area did not meet the -850 vs CSE criterion. The TRU output was 12.3A/15V. This area contained new compressor area piping which had no specific CP system installed during construction.

4.12 The following are key drivers for a full replacement CP system at St Fergus:

- Nearly 63% of the buried piping does not meet protection criteria.
- 82.43% shown to be non-compliant with the requirements of T/PM/ECP/2 for protection of the buried pipework from an inspection carried out in 2011.
- The existing CP system is over 40 years old and, combined with the corrosive coastal environment, has resulted in degradation of the above and below ground CP equipment. This includes increased coating deterioration. The protected potentials have been gradually registering more electropositive readings and the reason for the progressive failure of the system is possibly due to deterioration of the impressed current ground beds which have come to the end of their design life.
- The current demand has gradually increased due to deterioration of coating.
- As site upgrades and pipework modifications have been installed, little has been done to refurbish CP equipment to a new standard. To ensure that future monitoring can be carried out easily and efficiently, it is required that new equipment is installed in these areas.
- Two of the four transformer rectifiers cannot be further adjusted as they are now operating at their maximum output. The TRU outputs have been falling as seen from surveys conducted from 2003 onwards, indicating a possible increase in grounded resistance.

4.13 The present distributed system does not have control of individual or select ground bed outputs. Within a complex structure, there will be areas that would be subject to additional drains being in close proximity or connected to rebars in concrete and earthing. Therefore, ground bed output control of anode groups (powered by modular outputs) from a central or remote without resistive control offers significant benefits in any future system design.

4.14 The location of some of the above ground CP equipment are in hazardous areas and should therefore be relocated to safe areas or EExe rated to comply with latest standards (as these present locations are in contravention of DSEAR).

4.15 Table 5 below is based upon nearly 300 readings taken across the terminal (23 readings in South AGI, 76 readings in Plant 1, 113 readings in Plant 2, 62 readings in Plant 4 plus 15 around coupon test posts)

Protection Level for Carbon Steel	Potential Range	% Pipework	Impact
Under Protected	More positive than -850mV OFF	49	Corrosion may occur for carbon steel. The more positive of -850mV the higher the rate of corrosion. Once this is more positive than the natural potential of steel within its electrolyte we are dealing with accelerated corrosion where the pipework is anodic.
Protection	-850mV to -1150mV OFF	37	Accepted range where the rate of corrosion is considered to be negligible (i.e. less than 0.001mm per year) and where the osmotic evolution of Hydrogen is considered to not significantly compromise the coating efficiency.
Over Protected	More negative than -1150mV OFF	14	Where potentials are more negative than this, the long-term efficiency of the coating will begin to be compromised.

Table 5 – Results of CP Survey in 2019

4.16 NGGT require the CP system to meet the long-term strategy for the site, through the protection of buried pipework across the site. The existing system is already past its original design life and cannot be upgraded.

5. Probability of Failure

5.1 The current CP System has already failed as it does not protect all the buried pipework on the site.

5.2 The primary reason is due to the gradual degradation of the external coating systems on the pipework, which is beyond its original design life of 40 years, resulting in a greater current density requirement at specific locations which could not reasonably have been considered in the original design of the CP system.

5.3 The secondary reason for the progressive failure of the system is due to the deterioration of the impressed current ground beds which have come to the end of their design life such that they are no longer able to provide the current required for full protection of the below ground pipework.

5.4 Given the detailed survey and defect information made available to the HSE and their associated intervention notices due to the condition risk, assessing the condition status further to support understanding the probability of failure is not required as the CP system can be considered at end of life.

5.5 The best available visual representation of the protection levels of site pipework comes from the inspection carried out in 2011. A total of 256 buried pipe sections were surveyed with 82.43% shown to be non-compliant with the requirements of T/PM/ECP/2 for protection of the buried pipework, as per Figure 6 below.

[redacted]

Figure 6 – 2011 CIPS Alignment Results

6. Consequence of Failure

6.1 The consequence of a failed CP System is corrosion of pipework where coating has deteriorated and through wall corrosion has occurred which is characterised as a leak.

6.2 A failure of below ground pipework due to corrosion will result in a release of gas. This would be notifiable to the HSE under RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations) and could lead to HSE enforcement action and reputational damage.

6.3 We have no viable repair techniques which can be applied to leaking pipework, except for a leak clamp which would require it to be fully exposed. This means that in the case of buried pipework, any leak will nearly always result in an isolation being required which can result in flow restrictions or compressor units being made non-operational, impacting security of supply.

6.4 The HSE have previously indicated that it is their belief that the buried pipework should be subject to inspection under a Written Scheme of Examination (i.e., that it should fall within the requirements of the Pressure Systems Safety Regulations or PSSR). Any enforcement action by the HSE could lead to maintenance activities being brought into pressure systems inspection under PSSR, resulting in a more onerous intervention regime.

6.5 This investment seeks to eliminate gas leaks arising from through wall corrosion. These types of failures could shut down the entire terminal operation for varying periods of time. In all cases, the consequences will be catastrophic from a financial, safety and reputational perspective.

7. Options Considered

7.1 In total, four high-level options are considered here for management of the condition issues and associated risks as outlined in previous sections.

- Do Nothing
- Rehabilitation or partial replacement of the CP system
- Remedial coating repairs to remove localised current drain defects
- Replace the CP system

1. Do Nothing

7.2 Continue to operate without resolving the defect risk and relying upon a CP system which is not sufficiently protecting the pipework across site.

- **This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.**
- This option would not meet expectations set out by the HSE.
- This would leave the buried pipework at risk of failure at unknown rates which may result in a loss of containment event.
- Coating degradation will continue to occur and reach a critical point where no CP System can possibly by designed to protect the site.
- Remediation or failure would result in unplanned outages and shortfall of supply to the network.

2. Rehabilitation of Partial Replacement of CP System

7.3 Replace broken TRUs and depleted ground beds in addition to upsizing or reinforcing the existing CP architecture.

- **This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.**
- This option would not meet expectations set out by the HSE.
- The original CP System design is no longer fit for purpose. This is due to general degradation and breakdown of coating and the nature of being a complex site. Where new structures or changes in equipment have been added, the current requirement for pipework has also increased.
- Partially replacing or upgrading current sources would not be viable as although some areas of the site are still receiving adequate protection the CP system must be treated as a whole. Isolating the areas that are currently still receive the correct protection levels would not be feasible and would not result in the risks being ALARP. To separate the site into individual CP systems would require the pipeline to be exposed and isolated with numerous isolation joints to be installed to achieve localised electrical separation. Such individual sections would also require localised TRs, new pipework cable and ground beds.
- Partial replacement may provide useful CP current to protect some areas but would still leave other areas under protected. Increasing outputs of existing equipment, if operational, to compensate and reach other areas of site would result in over-polarisation locally, which is detrimental to the pipe coating.
- Coating degradation will continue to occur and reach a critical point where no CP System can possibly by designed to protect the site.
- Unknown rates of corrosion will continue, and risk of failure increase, which may result in a loss of containment event at an unknown point in the future.

3. Remedial Coating Repairs to Remove Localised Current Drain Defects

7.4 Complete excavation of >100 locations on site at an approximate cost of [redacted]. This would be followed by repair or replacement of asset coating to an 'as installed' condition in order to restore the primary protection method.

- **This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.**
- **This option is not economical as it would not address the failing of the secondary system which would therefore need replacing in the near future in addition to this work in order to sufficiently protect the pipework.**
- Where pipeline coating is the primary protection for buried assets, Cathodic Protection systems provide secondary protection to coating holidays. Newly installed pipelines and buried assets are never completely free of coating defects. An effective CP System is always required to maintain the asset.
- Remediating the largest current losses would reduce the current required to protect the site. However, as it is a complex structure, some current will still be needed to allow for current drains such as to earthing systems in addition to that required to protect the asset. This requires a fully operational, fit for purpose CP System, to distribute current to all areas and balanced in areas of current loss.
- Excavations of >100 locations would require significant outages which may not be possible while maintaining gas flow through the site.
- Site pipework has multiple different protective coatings used. Each different application of coating requires a different repair method. In many instances on site, it will be required to fully excavate underneath the pipe in order to carry out the repair. Excavations of this nature carry considerably more risk, time, cost and network restrictions.

4. Replace CP System

7.5 Install a completely new CP system and remove the current one.

- **This option is considered most economical for the lifecycle of the asset securing network availability and reducing risk.**
- The existing CP System is end of life and the current configuration is no longer able to provide effective CP current to all buried assets. By fully replacing the CP System it will return the system to A1 condition regenerating the full design life of 40 years.
- The new CP system would include:
  - New multi zone current sources capable of providing enough current to each area of the site
  - New horizontal and vertical groundbeds.
  - Remote monitoring reporting for maintenance
  - Central controller for system management
  - ER Probes for corrosion rates and future operating strategy
  - New Test Posts allowing effective monitoring and maintenance
  - Relocation of existing Test Posts outside of Hazardous areas
- The new CP system would also reuse any effective cabling and drain points from the existing system to ensure a cost effective, efficient plan is in place.
- Replacement of the CP System in order to provide protection (without over protecting) to all areas on site reduces digs, coating degradation, risk of failure, further outages and extends the operating life of the site beyond any of the above options.

8. Option Analysis and Selection

8.1 Considering the above information, the following table provides a summary of the high-level options available.

	Options Considered			
Solution considerations	Option 1 Do Nothing	Option 2 Rehabilitation or Partial Replacement of CP System	Option 3 Remedial Coating Repairs	Option 4 Replace CP System
Meeting HSE Requirements	Fail - risk prohibition notice Could result in the through wall corrosion and failure of below ground pipework that results in a release of gas notifiable to the HSE under RIDDOR.	Fail - risk prohibition notice Could result in the through wall corrosion and failure of below ground pipework that results in a release of gas notifiable to the HSE under RIDDOR.	Fail - risk prohibition notice Could result in the through wall corrosion and failure of below ground pipework that results in a release of gas notifiable to the HSE under RIDDOR.	Delivers in line with HSE expectations
Cost	Lowest Cost	Medium	Highest Cost	Medium Cost
Deliverability	No work required	Would not resolve the protection levels on site leaving pipework at risk. It would also add to coating degradation.	Would cause major site disruption which would impact upon delivery of other planned investments across the site.	Easiest to install
Compliance	Fails on a compliance basis/prudent operator and would not comply with our MAPD Safety Case, which requires us to maintain effective Cathodic Protection	Fails on a compliance basis/prudent operator and would not comply with our MAPD Safety Case, which requires us to maintain effective Cathodic Protection	Fails on a compliance basis/prudent operator and would not comply with our MAPD Safety Case, which requires us to maintain effective Cathodic Protection	Compliant
Environmental Impact	High potential for unplanned gas release due to degradation of protection	High potential for unplanned gas release due to degradation of protection	Requires lots of outages which require venting.	Low carbon footprint
Maintenance – Ongoing OPEX	High opex cost associated with loss of containment events	CAPEX cost required with ongoing high OPEX cost.	CAPEX cost required with ongoing high OPEX cost.	CAPEX investment with lowest OPEX cost
Maintenance – Risk	High risk - unsafe for personnel to work in vicinity of unmitigated defects	High risk - unsafe for personnel to work in vicinity of unmitigated defects	High risk - unsafe for personnel to work in vicinity of unmitigated defects which would continue to form in coming years	Sufficient protection in place to reduce formation of defects and adequately manage the risk
Security of Supply	Failure of station pipework could effect the terminals flow capability leading to a UK wide supply deficit	Failure of station pipework could effect the terminals flow capability leading to a UK wide supply deficit	Failure of station pipework could effect the terminals flow capability leading to a UK wide supply deficit	Ensures adequately protected pipework to minimise impact to security of supply
Overall viability	Not viable	Not viable	Not viable	Viable

Table 6 – Options Overview

8.2 Of the four options, three are discounted as they are not viable for compliance reasons. Therefore, the recommended solution is complete replacement of the CP system.

9. Final Option Selection, Costs, and Programme

9.1 The assessments outlined in this paper and the associated discounting and costing of options demonstrates there is only one viable and logical option to take forwards: Option 4 - Replace the CP system.

9.2 The focus is therefore on ensuring this is delivered at the lowest overall cost. The following factors support this:

- The St Fergus Short Term Strategy confirms the need for a replacement CP system to protect aging buried assets.
- The new CP system was designed on a case-by-case basis to ensure the lowest technology cost was taken forward.
- The competitive tender process undertaken for the Main Works Contractor provides assurance that a competitive market rate is paid for the programme.

Project Scope

9.3 A new replacement CP design is required to address the foregoing issues. This design intends to control the CP current from each group of groundbeds (typically four anodes located in a similar resistivity environment) via a dedicated power supply to each group controlled from a Kiosk and/or via a remote-control interface. No local adjustment will be necessary. The remote control will be sited at a convenient central location.

9.4 The following configuration is proposed:

- The CP design will be based upon a 40-year design life for cables, junction boxes and anodes. Electronics will be designed for a 30-year life, however; to be provided with suitable spares based upon a standard life of 15 years.
- The site will be broken down into specific CP zones, each of these zones will house multiple shallow vertical groundbeds installed via vac-ex or similar, wired to an anode junction box and one module of the CP power source specific to that CP zone of the site. The CP zones will be sized based on pipework configuration, size, soil resistivity and pipework density.
- CP power sources to be modular Switch Mode units with a centralised controller, remote view and alarming functionality.
- The new design shall utilise FeSi anodes (without chromium) conforming generally to ASTM A518 for anode beds. The chloride levels are low (analysis carried out on submitted soil samples by Intertek during December 2020 indicates 15ppm 1 to 2m depths and within 100ppm at 5m depths). The site has procured 420 nos of 3" (75mm) dia X 60" (1500 mm) long 50kg net weight solid Fe SI anodes with either 50m (402 nos) or 100m (18 nos) 25mm2 kynar/HMWPE cable lengths which are to be utilised for this project. Continuity and other integrity checks will be carried out prior using these anodes to ensure these are fit for purpose.
- Current distribution and protection parameters in the Compressor areas will be addressed as part of the design. Complex structure considerations (EN 14505) may have to be adopted (with stakeholder agreement) in this area.
- For areas where effective CP has historically been problematic to achieve, a number of corrosion monitoring Electrical Resistance (ER) probes will be installed to assess corrosion rates. The ER probes will be provided with a small GRP kiosk and AC power supply. Alternatively, use of solar power in lieu of AC is being discussed.
- During commissioning of the new CP system, where effective CP is not achieved, further installation of groundbeds may be required to boost the CP in these areas which is captured in

the cost range. The proposed design will have spare capacity and termination points for extra groundbeds to be installed within the junction boxes and CP power source sizing. The location of such will need to be agreed by the design team following review of the commissioning data.

- The design will address any interference to adjacent plant(s) piping that is continuous with St Fergus pipework as well as isolated pipelines such as Feeders 10,11,12,13, 24 and nearby pipework.

Final Costs and Programme

9.5 Table 7 provides a breakdown of the final costs for the project split by several cost categories. Due to this project being in delivery, and NGGT committing to spend due to the urgency of the project, the risk pot as showing in the table below is much less than would normally be expected. This is because the risks have either materialised or been retired.

9.6 In addition, some of the costs on this project were incurred during RIIO-T1. These are not being requested in this submission, however, would be predominately indirect design costs.

	Cost Category	Outturn Costs (£m)	Costs (£m) 2018/19 Price Base
	OEM costs	[redacted]	
Direct	EPC Estimate		
Indirect	EPC PM		
Direct	EPC Site Establishment		
Direct	NGGT Direct Company Costs		
Indirect	NGGT Indirect Company Costs		
	Contractor Risk		
Direct	NG Project Risk		
	FEED		
	Development / Optioneering		
	Land / Easements		
	TOTAL		
	Direct		
	Indirect		

Table 7 – Project Cost Breakdown

9.7 Table 8 shows the spend profile for our preferred option in 2018/19 pricing

£m 18/19	Prior Years	FY2022	FY2023	FY2024	FY2025	FY2026	Total	Comments
Cathodic protection Programme	[redacted]							

[2] Baseline funding post T2 BP ongoing efficiency & capitalised Opex adjustment

Table 8 – Spend Profile of Preferred Option

Tender Process

9.8 The original design process incorporated a contractor for each element of works at St. Fergus, however the decision to appoint a Main Works Contractor to complete all the works at St. Fergus has led us down a slightly different design process, which is more efficient from a delivery perspective.

9.9 The cathodic protection works were tendered as a package including corrosion remediation and actuator upgrade, in accordance with NGGT tender procedures. These works were competitively tendered on our minor gas construction framework, which contains six contractors capable of carrying out these types of works. This is a two-stage tender process;

- Tender information (including scope of works) is sent to all contractors on the framework for pricing against the scope. In this stage, three suppliers submitted a quote, and these were assessed against pre-communicated commercial and technical scoring criteria
- A select number of competitive bids are then taken forward for further assessment, clarification, and negotiation. In this tender, all three returns were taken into this stage to give National Grid the best technical and commercial tender.
- The best commercial and technical tender is then selected for award.

9.10 In this instance, the contract was awarded as a two-part design and build contract;

- Stage 1 was for design work only on actuators and cathodic protection, and a small amount of design and build corrosion management scope due to the timescales in place to meet customer outages [redacted]
- Stage 2 was an “opt-in” whereby the output and costs developed in stage 1 were assessed before progressing to the build option for the remainder of the works. This enables National Grid to assess value for money before committing to the entire contract.

RIIO-T2 Volume UIDs

9.11 Costs associated with this project have been assigned against the RIIO-T2 Unique Identifier (UID) [redacted] - ST FERGUS TERMINAL – CP Replacement. Table 9 provides a summary of the UIDs and associated funding for the scope of works proposed in this paper.

UID	Baseline volume of Intervention (By PP)	Baseline total funding available (£m 18/19)	Current volume of intervention	ECC total funding required (£m 18/19)	Output Year	UID funding requested through UM (£m)
	(by unit of measure)		(by unit of measure)	[redacted]		
[redacted] - ST FERGUS TERMINAL CP Replacement	Per site	[redacted]				

Table 9 – RIIO-T2 UID Output Table

9.12 The cost accuracy at this stage of the project is estimated at +/-10% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

NARMS Benefit

9.13 Following discussions with Ofgem in the NARM Development Monthly Meetings, it is proposed that for simplicity all the investments that arise from the UMs are collated and one NARMs update is provided in after the Plant & Equipment submission. For further details and a summary of UIDs please see Section 7 and Appendix 2 of the Asset Health UM overarching Document.

Deliverability Challenges

9.14 Due to the complexity of the site there are significant challenges in delivering this work, a few of which are highlighted below. This is all captured in the estimated cost.

- All excavations require additional planning, temporary works, and a more complex dig strategy as St. Fergus is a COMAH site.
- All digs will be carried out with vac ex.
- The dense population of buried services, plant and equipment leads to above ground complications with heavy machinery.
- Co-ordination with other projects on site to allow continued operation of a live strategically important site.
- Evolving scope leading to additional works required.

10. Appendices

Appendix 1 – St Fergus Short-Term Strategy

- Full report provided, filename:
- RIIO-T2 St Fergus Short Term Strategy V7.pdf

Appendix 2 – HSE liaison and communique

1. NGG St Fergus ME SIR 25-10-17 E2
2. NGG St Fergus Mech Eng Insp L 07-12-17
3. St Fergus Jan HSE Intervention_27JAN20.pdf
4. St Fergus HSE Update 140720.pdf
5. ST Fergus ALARP Demonstration (Oct-19).pdf
6. ST Fergus ALARP Demonstration (Jun-20).pdf
7. ST Fergus ALARP Demonstration (Oct-20).pdf
8. ST Fergus ALARP Demonstration (Mar-22).pdf

Appendix 3 – Detailed project programme and cost profile

St Fergus PAC3419 Cathodic Protection November 2022 Programme

Appendix 4 – Future Energy Scenarios

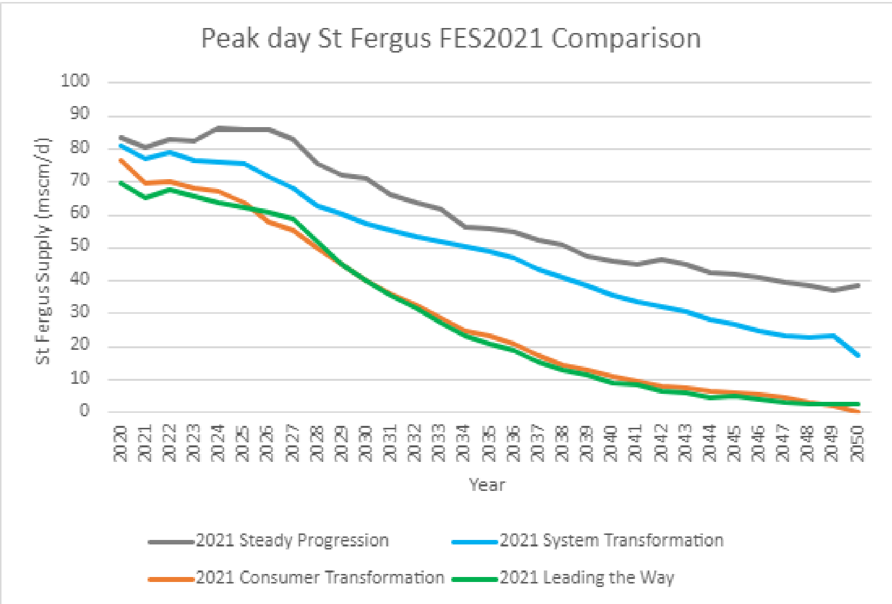

Figure 7 - Peak Day St Fergus FES 2021 Comparison

Appendix 5 – How Cathodic protection is measured

The main standard measurements of cathodic protection are as follows:

- Pipe-to-Soil Potential (ON Potential) - The potential of a pipeline at a given location is commonly referred to as the pipe-to-soil potential. It results from the corrosive electrolytic reaction between the buried pipe and its surrounding soil (the electrolyte). It is measured between the pipeline and a reference electrode (most commonly copper sulphate), placed in the soil directly over the pipeline. It is also known as the ON potential because the measurement is made while the CP system is energised.
- Instant OFF Potential - When a pipe-to-soil measurement is made, the pipeline potential will appear to be more negative than its true potential, due to the voltage drop from energy losses in a resistor. The instant OFF measurement corrects for these errors; the CP current is briefly interrupted to produce a "true" pipe-to-soil potential, free from undesirable IR drop effects and before any appreciable depolarisation has occurred. This is a truer measure of the level of protection afforded to the pipeline. If it is not possible to disconnect the CP momentarily then an alternative approach is the use of a corrosion coupon (see below).
- Coupon Current - Corrosion coupons connected to cathodically-protected structures can be used to monitor the effectiveness of the CP system. A coupon is a representative sample of the pipeline material, buried close to the pipe so that it is subjected to the same environment. Connected to the pipeline via a test post, it simulates how the pipeline would react if there were a defect (often referred to as a "holiday") in its coating. It is especially useful when it is not possible to interrupt the CP system, since instant OFF potentials can conveniently be measured by interrupting the CP connection to the coupon. The measurement of current flow to/from the coupon can also be determined by measuring the voltage across a shunt. The surface area of the coupon allows the current density to be calculated.

These measurements may be taken at the Transformer Rectifier or, in the field, at CP test posts/stations. However, they are only representative of the pipeline at that point – and for a short length either side.

Close Interval Potential Survey (CIPS) - fills in the “gap” between measurements taken at test points. A direct connection is made to the pipeline and this trailing wire is unwound from a spool as the technician walks along its length. As he goes, the TR current output is interrupted to enable the technician to take a pipe-to-soil OFF potential measurement at approximately 1m intervals. On pipelines with multiple TRs, all the outputs (or at least those that influence the potential measurement at that point) must be interrupted synchronously. Interruption cycle times vary but the selected "on" period is longer than the "off" period to limit depolarisation of the pipeline during the survey.

Appendix 6 – Ofgem SQs

Ofgem supplementary questions submitted in response to an early draft and NGGT responses:

20221222 StF CP SQ Batch 1