Engineering Justification Paper

Electrical, Instrumentation & Control Upgrade Programme

Final Version

Date: December 2019

Classification: Highly Confidential

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2 Introduction

2.1 General Background

This paper sets out SGN's investment proposal relating to the upgrade of our electrical and instrumental assets.

SGN have put forward a number of operational gas sites which require upgrade and refurbishment work to SGN's electrical, instrumentation and control equipment and systems.

The worklist included within this programme of works has been generated from carrying out asset health and criticality surveys and results from site electrical and instrumentation tests and inspections.

E&I fault forms and results have also been assessed and the outcome of these have been fed into the worklist.

This works will also include compliance to functional safety management systems

SGN have followed the guidance presented in the HSE's Research Report 823 – Plant Ageing Study Phase 1 Report, which states the following:

"It is worth recognising that the original design life for chemical plant, is typically of the order of 25 years. This would place any plant commissioned before 1983 in this category – a substantial proportion of chemical and process plant in the UK probably falls within this definition. However, for Electrical, Control and Instrumentation (EC&I) equipment, lifecycles are often significantly shorter than lifetimes of main plant. This is especially so for modern digital plant for which a lifecycle (start of operation to replacement) duration of 10 to 15 years may be more appropriate."

HSE Research Report 823

2.2 Site Specific Background

The sites which form this programme of works are national offtakes and pressure reduction stations which require major replacements and upgrades to their electrical infrastructure as well as their instrumentation and control systems.

Under the Electricity at Work Regulations, SGN have an obligation to ensure its electrical systems and equipment are in a safe condition to operate and maintain. SGN also have an obligation to comply with the IET Wiring Regulations (BS7671:2018).

SGN carry out routine inspection and testing on their national offtakes and pressure reduction stations, and the following sites have been identified for electrical, instrumentation and control upgrades:

Table 1: Summary of Scotland LDZ sites

Site	Site	Comment
Offtake	Bathgate	E&I scope only
Offtake	Burnhervie	E&I scope only
Offtake	Kinknockie	E&I scope only
Offtake	Langholm	E&I scope only
Offtake	Stranraer	E&I scope only
PRS	Greenock	E&I scope only

PRS	Old Kilpatrick	E&I scope only
PRS	Carleith	Joint scope with Mechanical & E&I
PRS	Granton	Joint scope with Mechanical & E&I

Table 2: Summary of South of England LDZ sites

Site	Site	Comment
Offtake	Mappowder	E&I scope only
Offtake	IOG Shutdown	E&I scope only
PRS	Bucklebury	E&I scope only
PRS	Butts Ash	E&I scope only
PRS	Gastons Wood	E&I scope only
PRS	Paradise Lane	E&I scope only
PRS	Portsdown Hill PRS	E&I scope only
PRS	Sett Copse	E&I scope only
PRS	Sopley	E&I scope only
PRS	Rochester	E&I scope only
PRS	Isle of Grain PRI	E&I scope only
PRS	Crossbush	E&I scope only
PRS	East Morden	Joint scope with Mechanical & E&I
PRS	Hillside	Joint scope with Mechanical & E&I
PRS	Reading A	Joint scope with Mechanical & E&I
PRS	Braishfield C	Joint scope with Mechanical & E&I
PRS	Woking	Joint scope with Mechanical & E&I
PRS	Battle PRI (MP & HP OUTLET)	Joint scope with Mechanical & E&I
PRS	Godstone PRI	Joint scope with Mechanical & E&I
PRS	Hurst green	Joint scope with Mechanical & E&I
PRS	Boxhill	Joint scope with Mechanical & E&I
PRS	Shatterling	Joint scope with Mechanical & E&I
PRS	Gillingham	Joint scope with Mechanical & E&I
PRS	Smarden PRI	Joint scope with Mechanical & E&I
PRS	Aylesham PRS	Joint scope with Mechanical & E&I

3 Equipment Summary

The equipment which will form the scope of works is the electrical, instrumentation and control equipment on above 7 bar pressure reduction stations and offtake sites.

This includes distribution equipment which provides power to key systems on site such as telemetry, pre-heating and pressure and temperature sensors which are fed back to GCC l via telemetry.

Figure 1: Asbestos Containing Distribution Equipment – Soutra Offtake

A number of SGN's electrical kit contains asbestos as this material was used within fused switchgear, fuse boards or behind ceramic fuses. A lot of SGN's older electrical kit does not allow equipment to be safely isolated using SGN Safe Isolation Procedure.

On SGN's older sites a lot of the kit was installed pre Atmosphere Explosive (ATEX), and as a result we are non-compliant with ATEX/DSEAR and there is a number of remediation works to be done.

In 2018, SGN commissioned the Health and Safety Laboratory to carry out an electrical safety gap analysis, and below is one of their observations, which SGN aim to close in GD2:

> *"Whilst most modern SGN sites have rotary double pole isolation which is the easiest to lock off quickly, at some sites there are a number of older isolation devices which do not lend themselves to easy lock off in spite of the wide range of adaptors available in the lock off kit provided to staff."*
>
> ***HSL Electrical Safety Gap Analysis***

SGN must comply with the Electricity at Work Regulations 1989 and the Dangerous Substances and Explosive Atmospheres Regulations 2002 to ensure safe systems of works are being implemented and to ensure electrical systems and equipment is adequality designed to ensure safe operation and maintenance of their kit.

The sites which have been targeted have been derived from fault form returns, results from annual maintenance regime, E&I Site surveys, electrical inspection and test result sheets and operational feedback. The E, I &C equipment which forms part of a mechanical site rebuild or support mechanical component upgrades such as gas preheating systems does not form part of this scope of works.

4 Problem Statement

The main issue with Electrical, Instrumentation and Control equipment is obsolescence, which is usually ultimately driven by spares availability. Older equipment will be analogue, and almost all new equipment is digital.

Other considerations are training, competence and familiarity with the ageing instrumentation and control equipment on site – as this is degrading with the ageing workforce. Also, instrumentation and control equipment which requires auxiliary software/equipment is also ageing and support for this kit is no longer available.

Why are we doing this work and what happens if we do nothing?
SGN are carrying out this work as the kit on some of our operation sites is now obsolete and is showing signs of deterioration. A significant number of problems are being found as part of electrical inspection and testing.

Failure of electrical kit and electrical protective devices can result in the risk of SGN colleagues being exposed to electrical shock or injury, which is in contravention of the electricity at work regulations.

This package of works also includes for the replacement of deteriorated electrical and instrumentation kiosks which have potential ingress of water onto electrical distribution systems and equipment. This could result in electrical outages, site downtime, damage to equipment as well as potential for electrical shock and injury.

SGN must ensure that their safe systems of works (SSOW's) and their electrical safety rules are complied with and followed. This ensures compliance with the electrical safety at work act and HSG8G, Electricity at work and safe working practices.

As a result, SGN commissioned an independent audit, to look at safe electrical isolations and benchmark their electrical safety rules against current best practice in industry. The Health and Safety Laboratory (HSL) who are the HSE's scientific division, carried out the audit.

As part of this audit, it was observed that SGN have a number of electrical distribution equipment which is not lockable, thus not lending itself to safe and secured isolation. As part of these E&I upgrade works, electrical distribution kit will be upgraded to allow for equipment which can be safely and securely isolated.

What is the outcome that we want to achieve?
The outcome of this work programme would be to ensure SGN operational kit is safe and reliable and complies to meet the requirements of the 18th edition IET wiring regulations (BS 7671) thus conforming to the Electricity at Work Regulations.

How will we understand if the spend has been successful?
Network E&I will revisit the sites which have undergone E&I upgrade works, and each site will be re-surveyed and the asset and health criticality scores of each site will be revised accordingly. Through careful project management and supervision, SGN should ensure the required outcome be achieved within the set budget and timescales allowed for.

4.1 Narrative Real-Life Example of Problem

South LDZ - Reading A Compressor Site
Reading A is a site which will undergo an E&I rebuild within this work programme. The site has Ulysses Telemetry which is now obsolete and unsupported.

The site also has remote pressure control and used TCS controllers which are now obsolete as well as old E-P converters.

The electrical distribution equipment is obsolete with multiple form 4 panels which are unsupported and redundant compressor kit.

The earth cables are showing signs of deterioration and have high resistivity readings. The site also has obsolete instrumentation, while not a large CAPEX cost, it will invariably represent best value for money changing the obsolete instrumentation at the same time as the electrical works.

This work will help to support the mechanical heating and filter project.

Figure 2: Reading A – Control Room Ceiling

Figure 3: Redundant Oil Filled Transformer

Figure 4: Obsolete Pressure Transmitter

Figure 5: Extract from Electrical Test Results showing High Resistance

READING 5 SITE GENERIC SCHEDULE OF TEST RESULTS

DB reference no; Distribution Circuits
Location; No7 LV Sub Station
Zs at DB (Ω) 0.38
I_{pf} at DB (kA) 8.605
Correct supply polarity confirmed ☑
Phase sequence confirmed (where appropriate) ☑

Details of circuits and/or installed equipment vulnerable to damage when testing

Details of test instruments used (state serial and/or asset numbers)
Continuity 101486425
Insulation resistance 101486425
Earth fault loop impedance 101486425
RCD 101486425
Earth electrode resistance 101486425

Tested by:
Name (Capitals) SIMON DEBENHAM
Signature [signature] Date; 28/11/2017

Circuit Details									Test Results												
		Overcurrent device				Conductor details			Ring final Circuit continuity (Ω)			Continuity (Ω) (R_1 + R_2) or R_2		Insulation resistance (MΩ)		Polarity	Zs (Ω)	RCD (mS)		✓	Remarks (continue on separate sheet if necessary)
Circuit number	Circuit Description	BS (EN)	type	rating (A)	Breaking capacity (kA)	Reference Method	Live (mm^2)	cpc (mm^2)	r_1 (line)	r_n (neutral)	r_2 (cpc)	(R_1 + R_2)	R_2	Live - Live	Live - Earth	Insert ✓ or X		@ $I_{\Delta n}$	@ 5 $I_{\Delta n}$	Test button operation	
R	Distribution Board 1 and 2	88	2	100	70	B	25.0	CA	X	X	X	0.31	X	>999	>999	✓	0.69	X	X	X	Exceeds Zs max
Y	Distribution Board 1 and 2	88	2	100	70	B	25.0	CA	X	X	X	0.31	X	>999	>999	✓	0.69	X	X	X	Exceeds Zs max
B	Distribution Board 1 and 2	88	2	100	70	B	25.0	CA	X	X	X	0.31	X	>999	>999	✓	0.69	X	X	X	Exceeds Zs max
R	Distribution Board 3	88	2	80	70	B	16.0	CA	X	X	X	0.11	X	>999	>999	✓	0.43	X	X	X	OK
Y	Distribution Board 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Scotland LDZ - Langholm

The Electrical, Instrumentation and Control assets at this site have been in operation for around 30 years providing system alarms, flow & pressure measurement, gas control functionality and remote telemetry monitoring. It has now reached its end of useful life. This equipment is obsolete, with manufacturers support and spares no longer being available, and this install does not meet current regulations and standards. The existing system is installed in above ground control rooms and ageing composite kiosks and have associated issues with access, water ingress, confined spaces and ventilation problems.

The project proposal is to install at Langholm Offtake, new electrical, Instrumentation, control system and telemetry assets to meet current standards and regulations. The build will be installed in above ground kiosk/enclosures, with field instrumentation systems relocated into these. Positioning of the EIC&T equipment above ground will eliminate ground water ingress and provide a well ventilated, safer installation for the site.

The site electrical distribution equipment is obsolete and will be replaced and a new isolation transformer installed. Some final circuits feeding hazardous area lighting and power, do not have sensitive earth fault protection. The earth bar is overcrowded and does not provide suitable operational access for test and maintenance.

A lighting protection risk assessment is required, and surge protection equipment should be installed. There is no earthing installed to the skids on site, so this will also form part of the scope of works.

Figure 6: Degrading Kiosk at Langholm Offtake

4.2 Spend Boundaries

The tables in section 2.2 represent the workload for this workstream. Each site in the tables consist of slight variations on scope. As a high level indicator, an Electrical, Instrumentation and Control rebuild would consist of the following elements:

- Installation of an isolation transformer where the site does not currently have one to ensure continuity of supply and earthing.
- New electrical distribution system where previous electrical distribution has shown signs of insulation resistance failure or degradation or non-conformance with the electrical wiring regulations or has been shown to contain asbestos containing materials.
- New/remediation of site earthing systems where earthing is required for continuity of supply and safety reasons.
- New electrical intake kiosk where the existing kiosk has shown significant sigs of degradation (water ingress/cracking/subsidence).
- Replacement instrumentation such as pressure, temperature sensors etc which are obsolete or requiring replacement due to DSEAR requirements (Dangerous Substrates and Explosive Atmospheres Regulations).
- New site lighting renewal where required.

5 Probability of Failure

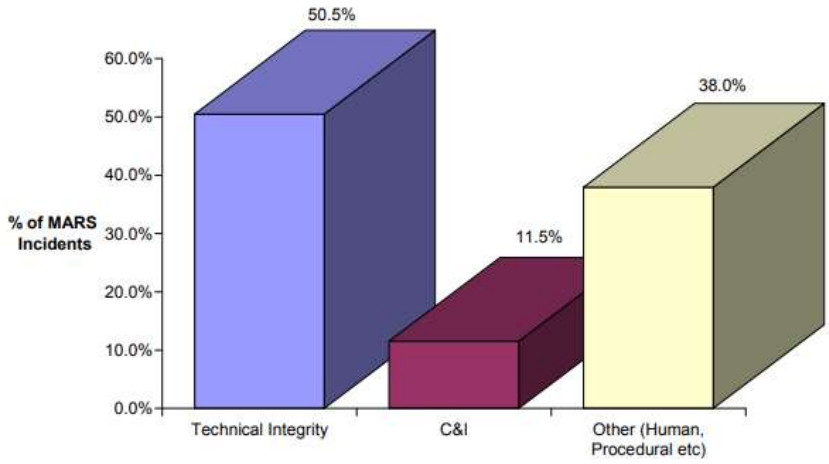
This work stream is concerned with the asset health and criticality and the ageing profile of SGN electrical, instrumentation and control systems and the potential for a major hazards as a result of these ageing assets.

The below is an extract from the MARS (EU Seveso II major hazard incidents) database:

> *" In terms of major accidental potential events at major hazard installations, the MARS data provides the most appropriate basis to assess the significance of ageing. The study has determined that approximately **60% of incidents are related to technical integrity and, of those, 50% have ageing as a contributory factor.** It is therefore concluded that plant ageing is a significant issue."*

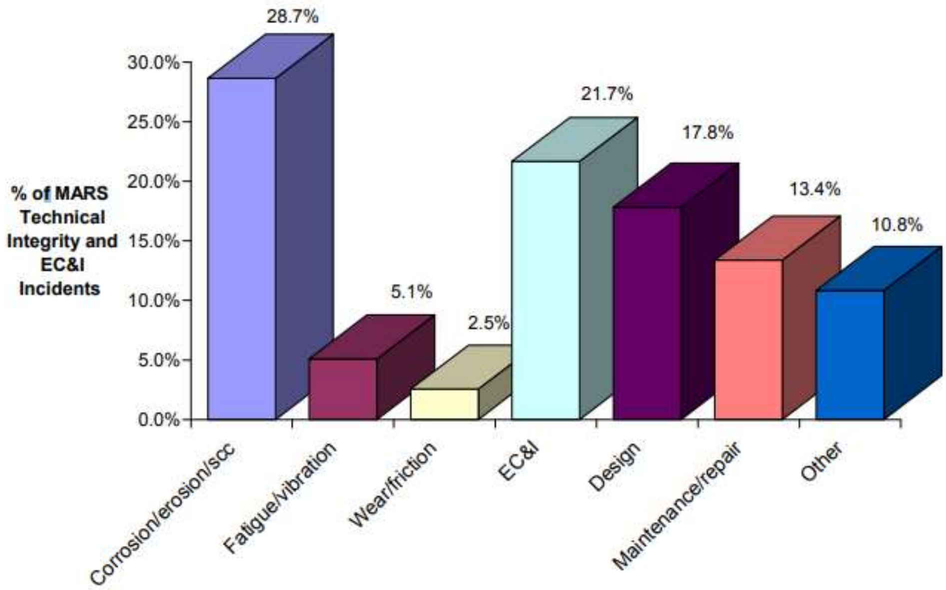
The below data has been gathered from the RIDDOR UK (Reporting of injuries, Diseases and Dangerous Occurrences Regulations database), MARS EU (Major Accident Reporting System) and MHIDAD Worldwide (Major Hazards Incidents Data Service):

Figure 7: High Level categorisation of MARS incidents



Looking at the technical Integrity category in more detail, the breakdown of causes of these incident is illustrated on Figure 8.

Figure 8: Causes of Technical Integrity Incidents in MARS database



This data shows that approximately 50% of technical integrity and E,I&C related incidents are age related.

"60% of 'potential major accident' incidents are Technical Integrity or Control and Instrumentation related issues and 50% of those are associated with ageing of one type or another".

An analysis of RIDDOR loss of containment accidents where Electrical, Control and Instrumentation issues were a significant factor has been conducted. To summarise the analysis:

- EC&I issues were associated with 36 out of 3143 loss of containment accidents, just over 1%.
- Almost 60% of EC&I issues were associated with Maintenance, one third were associated with Design.
- Over 30% of issues were associated with level detection, of these 90% are associated with maintenance.
- Other significant issues include Loss of Site Power, Software failures and problems with upgrading old control systems.

In considering ageing, because of the limitations of the data provided, it was not possible in every case to definitively classify EC&I issues as ageing or otherwise. However, the following analysis could be inferred;

An analysis of MARS incidents where Electrical, Control and Instrumentation issues were a significant factor has been conducted. To summarise the analysis:

- EC&I issues were associated with 34 out of 348 accidents, 10%.
- 44% of EC&I issues were associated with Maintenance, 26% were associated with Design.
- 15% of the issues were associated with level detection, all associated with maintenance.
- Other significant issues include Loss of Site Power and Software failures, including problems with upgrading to new DCS.

In considering ageing, because of the limitations of the data provided, it was not possible in every case to definitively classify EC&I issues as ageing or otherwise. However, the following analysis could be inferred;

Table 3: MARS EI&C Analysis

Ageing Classification	Number	Percentage of EI&C Accidents	Percentage of all accidents
Not Ageing (no)	13		
Possibly Ageing (?)	17		
Ageing	4		
Aged	0		
Total EI&C issues	34		
Possible Ageing EI&C	21	62%	6%

From this it can be seen that up to around 60% of EC&I related incidents may be associated with ageing. On this basis up to 6% of all MARS incidents may be associated with ageing EC&I.

5.1 Probability of Failure Data Assurance

SGN carry out annual inspection and test on all of their electrical, instrumentation and control equipment. This regime is managed through SGN's maintenance management systems MAXIMO which schedules the following:

Table 4: Maintenance Regime

Location	Task	Frequency	Work Schedule Tag
National Offtake	Full electrical inspection and test	2 yearly	E0001A - Maint 11 Full inspection & test
National Offtake	Inspection & Functional check	Annual	E0002A - Maint 11 Inspection & Functional check
PRS	Full electrical inspection and test	2 yearly	E0001A - Maint 11 Full inspection & test
PRS	Inspection & Functional check	Annual	E0002A - Maint 11 Inspection & Functional check

As part of these work orders SGN are required to complete full inspection and testing sheets, compiling test results, DSEAR inspection results and also any site observations which may have been made. These sheets in conjunction with Networks condition surveys have identified this workload.

6 Consequence of Failure

Loss of Supply to Customers
In relation to E&I Asset upgrade works, loss of supply to customers has not been considered as possible failures in relation to this type of equipment would not lead to reduced gas supply to the network.

Safety Impact of Failure
Prolonged failure to assets on site can lead to severe corrosion and asbestos to assets. This can be particularly problematic to SGN's E&I Operations team. Ageing electrical equipment where cables come lose or possible arcing occurring posses a major risk of electrocution on site, therefore it imperative that SGN maintain these assets.

Environmental Impact
Specific failures in relation to E&I asset degradation are difficult to specify. However, SGN have previously not had any environmental issues due to failures and therefore do not envisage any future impact.

The table below has been taken from HSE's Research Report 823 – Plant Ageing Study Phase 1 Report:

Table 5: Incidents related to Ageing Plant

Class	Total	Deaths			Injuries		
	No. Incidents	Incidents	Total Deaths	Deaths per Event	Incidents	Total Injuries	Injuries per Event
All Events	348	57	124	2.2	140	4201	30.0
All Integrity	149	11	35	3.2	51	768	15.1
Integrity Ageing	57	3	4	1.3	21	125	6.0
C&I Ageing	21	2	4	2.0	4	32	8.0
Other Ageing	23	2	3	1.5	7	47	6.7
All Ageing	96	7	11	1.6	30	183	6.1

The following are examples of ageing electrical, instrumentation and control issues above those SGN specific issues mentioned in section 4 of this report.

Table 6: Safety Critical Instrumentation Incident

Lessons Learnt	All safety critical instruments need to be identified and appropriate maintenance and testing must be carried out to ensure that interlocks are available when required.
Data Source	RIDDOR Loss of Containment Data
Primary Cause of Incident	Ageing of safety critical level instrument.
Description of Incident	A high level switch failed resulting in the interlock on the inlet valve failing to close during a tank filling operation. The tank over-filled and approximately 600 kg of flammable product was released into the

	bund. The tank was fitted with a high level float switch that failed due to a hole in the float caused by corrosion or old age.
Risk Control System	Identification of safety critical instruments. Periodic maintenance and testing of safety critical instruments.

This incident is relevant to this business case as SGN are proposing a package of works to identify and update relevant documentation around SGN's safety critical systems – covered in Appendix A.

Other SGN Specific Consequences:
Other consequences relating to the failure of SGN electrical, instrumentation and control systems on SGN operational sites are listed below:

- Loss of telemetry

The consequence of having a telemetry or communications failure can be catastrophic if not addressed in a timely manner. Telemetry helps to reduce the risk of a hazard occurring by providing GCC with situational awareness and network visibility of remote sites to maximise optimum operation of the networks.

The telemetry monitors many parameters which ensures notification of site issues before major problems occurs. It provides GCC with situational awareness, network visibility, and enables optimum operation of the gas network.

This will also have an impact on OPEX costs as sites will be required to be manned and also an impact on the environment as there will be travel requirements to and from site more frequently.

- Loss of Gas Quality

The GC is a crucial piece of kit SGN must continue to maintain. As the equipment is crucial to the fiscal element of the company, SGN are required to obtain accurate readings in order to remain GSMR compliant. If the GC was to fail at any SGN site, that site would be required to stop flow as SGN would no longer be compliant with GSMR regulations. As a Gas Transporter SGN are obliged under statute, license conditions and Network Code for the management of the quality and quantity of gas conveyed on its Network, document 'SGN/PM/GQ/8' highlights the legal requirements which must be met. SGN will be liable to fines/penalties if failure to meet GSMR regulations occur.

- Metering

Customers would not be lost due to a fault or failure on the metering system. Gas will still pass through the network and supply customers as normal. However inaccurate readings can lead to severe ramifications in the area of billing and fiscal revenue for SGN and will impact customers billing.

- Gas Odorisation

Natural gas is odourless and therefore causes an immediate risk to the general public. In the case of a complete LGT system failure, un-odourised gas would not be allowed to flow in to the network which would then lead to a Gas site being shut down until odourised gas can flow again. This has the potential of affecting thousands of customers, therefore it is critical that all SGN LGT gas sites remain operational at all times

7 Options Considered

Replace on Failure
This is an option, however if the equipment in question is allowed to fail before replacement, this would most likely increase the cost of replacement by >20%. This is because if there was an issue with the electrical distribution, a temporary generator would be required to keep the operational site running. If telemetry or odorisation was lost, OPEX cost would be incurred as the site would need to be routinely manned.

The CAPEX cost would also increase as there may be a need for external resource to carry out project management in the event of an unplanned project.

This option has been costed using the pre-emptively replace costs with a +20% mark up on prices to estimate the assumed additional spend previously mentioned.

The sum of £8,464,763.42 is the estimated benefit of eliminating potential hazards across 34 sites over a period of 45 years based on avoidance of causalities. The figures used in this calculation have been obtained from IGEM/SR/15 and the Greenbook model.

Table 7: Cost Avoidance Summary

Category	Numbers	Greenbook methodology figures	Maximum Tolerable Individual Risk	PRI pipeline depreciation period in years	Resulting cost
Fatalities	2	£16,170,000	0.000001	45	£1,455.30
Non-fatal incidents	1	£185,000	0.000001	45	£8.33
Major offsite incident affecting water, supply, food chain, or housing for a period circa 1 month	1	£5,000,000	0.001	45	£225,000.00
Non-serious "nuisance" / odour incident	1	£50,000	0.01	45	£22,500.00
Total/site					£248,963.63
Scotland	9				£2,240,672.67
South	25				£6,224,090.75

Repair on Failure
This package of works does not cover the small-scale repairs which would be associated with E&I costs. For example, small repairs being the replacement of a single RCD, or replacement of a single up and over kiosk – generally, these small scare/individual repairs would be covered under a rolling integrity budget. This is being covered in another Engineering Justification Paper.

Pre-emptively replace
This is the preferred option, as a package of works has been identified through a series of site health and criticality surveys and review of site-specific inspection and test results.

These sites have been costed using costing templates which were provided for similar size and scope projects in GD1.

Pre-emptively rebuild
This option is similar to Option 1 of the CBA, however as the scope of option 1 concentrates on the replacement of assets which are showing signs of degradation and obsolesce, this scope of work will seek to fully rebuild all electrical, instrumentation and control assets regardless of condition.

The premise behind this is that a replacement will concentrate on replacing elements of the overall electrical, instrumentation and control installation whereas with the rebuild, it will be a complete re-build of the full electrical, instrumentation and control installation – regardless of condition of some of the installation's equipment.

This is not the preferred option as in this case it is not the most cost effective, as it will involve the replacement of assets which generally have a longer lifecycle than other assets – an example of this being cables, earth nests etc.

Pre-emptively Repair
This option has not been considered, as this work would be covered under a rolling budget of integrity repair works.

Do Nothing
Do nothing is not an option, as doing nothing could result in SGN not complying with the Electricity at Work Regulations 1989 with regards to safe working practices and the safe design, maintenance and operation of SGN electrical systems and equipment and also non-compliance with the Dangerous Substances and Explosive Atmospheres Regulations 2002.

7.1 Replace on Failure Option Summary

The technical detail of the option i.e. capacity, system rating, availability etc.
This option is to allow electrical, instrumentation and control equipment to fail before replacing them at a component level. This will result in increased project cost as all materials will be ad-hoc (full price) purchases, and there will be a larger installation and commissioning costs. This could also impact OPEX coast as to replace the faulty components as there will be increased downtime if for example the electrical distribution was to fail – this could compromise the site telemetry or gas pre-heating systems.

The basis for the cost estimate/unit cost

The costs used for these have been compiled from GD1 projects of similar scopes. A mark up of 20% has been applied to account for individual design requirements and increased time on site and project management costs as these are ad-hoc projects.

The perceived benefits of the option

There could be a decrease in workload if SGN see a low failure rate, however this could lead to placing SGN's employees and those who work near SGN's electrical systems at risk and potential non-compliance with the electricity at work act or the IET wiring regulations.

Delivery timescales

This will be very varied and mostly dependent on the type of failure, the time of year and the availability of spares or lead time for parts. The delivery timescale of a replacement/upgrade project could take a matter of months, and for a non-critical fault it could be under a year – depending on resource and part availability as well as the completion of the design approval and appraisal process.

Key assumptions made

It is assumed that any failures seen will reflect what the result and record sheets are showing, and that replacement/upgrade projects based on failure will be similar in scope/size to those in the pre-emptive work plan.

Any other items that differentiate the option from the others considered

This is to replace on failure, as opposed to pre-emptively replace.

7.2 Pre-emptively Replace Option Summary

The technical detail of the option i.e. capacity, system rating, availability etc.

The scope of this option is highlighted in section 4.2 spend boundaries. There should not be any downtime here for systems such as pre-heating, telemetry or power to other non-essential equipment.

The basis for the cost estimate/unit cost

The costs for this work have been derived from previous project work, and a quotation provided by Major Construction Projects – an example cost estimate has been provided in the appendix below. SGN will be reducing their costs through this programme of works as SGN will go to tender for a package of larger works as opposed to ad-hoc upgrade works. This should decrease material and labour costs

The perceived benefits of the option

Ensure compliance with key policy, procedures, best practice and regulations. Reduce project costs through package of work efficiencies and reduce down time and labour time on site.

Delivery timescales

This package of works will be delivered in the 5-year GD cycle.

Key assumptions made

It is assumed that SGN will receive the allowance to carry out this workload, it's also assumed that SGN will have carried out strategic delivery plans pre-GD2 to ensure maximum efficiencies during GD2 to deliver the workload.

Any other items that differentiate the option from the others considered

This is a pre-emptive work programme to delivery key components. This varies from option three which is to carry out a full pre-emptive site rebuild and also varies from option one which is to replace components on failure.

7.3 Pre-emptively Rebuild Option Summary

The technical detail of the option i.e. capacity, system rating, availability etc.

The scope of this option is highlighted in section 4.2 spend boundaries. However, whilst SGN are mobilizing site, the scope will be to also replace electrical and instrumentation components which are not showing any signs of disrepair or degradation, but which may be obsolete or may become obsolete in the near future. There should not be any downtime here for systems such as pre-heating, telemetry or power to other non-essential equipment as this work will all be planned, and downtime would be kept to a minimum.

The basis for the cost estimate/unit cost

The costs for this work have been derived from previous project work, and a quotation provided by Major Construction Projects – an example cost estimate has been provided in the appendix below. SGN will be reducing their costs through this programme of works as SGN will go to tender for a package of larger works as opposed to ad-hoc upgrade works. This should decrease material and labour costs. As this cost is to rebuild as opposed to replace defective components – Network have added a markup of 30% to the pre-emptively replace work programme.

The perceived benefits of the option

Ensure compliance with key policy, procedures, best practice and regulations. Reduce project costs through package of work efficiencies and reduce down time and labour time on site.

Delivery timescales

This package of works will be delivered in the 5-year GD cycle.

Key assumptions made

It is assumed that SGN will receive the allowance to carry out this workload, it's also assumed that SGN will have carried out strategic delivery plans pre-GD2 to ensure maximum efficiencies during GD2 to deliver the workload.

Any other items that differentiate the option from the others considered

This is a pre-emptive work programme to delivery full electrical and instrumentation rebuild. This varies from option two which is to carry out a pre-emptive component replacement and also varies from option one which is to replace components on failure.

7.4 Options Technical Summary Table

Table 8: Options Technical Summary

Option	First Year of Spend	Final Year of Spend	Volume of Interventions	Equipment / Investment Design Life	Total Cost
Scotland LDZ					
Replace on Failure	2022	2026	9	25	2.97
Pre-emptively replace	2022	2026	9	25	2.38
Pre-emptively rebuild	2022	2026	9	25	3.09
South of England LDZ's					
Replace on Failure	2022	2026	26	25	2.42
Pre-emptively replace	2022	2026	26	25	6.03
Pre-emptively rebuild	2022	2026	26	25	7.77

7.5 Options Cost Summary Table

Table 9: Cost Summary - Scotland

Option	Cost Breakdown	Total Cost (£m)	
		Scotland LDZ	**South of England LDZ's**
Pre-emptively replace	Please see Appendix C for cost breakdown	2.38	6.03
Pre-emptively rebuild	Please see Appendix C for cost breakdown – plus 30% has been added to these cost to represent increased scope of works (From E&I replacement to E&I rebuild)	3.09	7.77

Replace on Failure	Please see Appendix C for cost breakdown – plus 20% has been added to these cost to represent the increased elements of an ad hoc project (increased PM cost, increased materials and labour and longer commissioning times)	2.97	2.42 (this is low as not all 23 sites will fail within the GD2 period; thus a lower capex will be required)

8 Business Case Outline and Discussion

The tables below highlight the key options that SGN have investigated in detail. As E&I degradation has a major risk to SGN Personal, SGN have decided that pre-emptive replacement was the optimum choice for the GD2 period.

SGN have considered replacing on failure however the increased cost of works makes this option unviable as discussed in table 10.

8.1 Key Business Case Drivers Description

Table 10: Summary of Key Value Drivers

Option No.	Desc. of Option	Key Value Driver
1	Replace on failure	• This is an option, however if the equipment in question is allowed to fail before replacement, this would most likely increase the cost of replacement by >20%. This is because if there was an issue with the electrical distribution, a temporary generator would be required to keep the operational site running. If telemetry or odorisation was lost, OPEX cost would be incurred as the site would need to be routinely manned. • The CAPEX cost would also increase as there may be a need for external resource to carry out project management in the event of an unplanned project. • This option has been costed using the pre-emptively replace costs with a +20% mark up on prices to estimate the assumed additional spend previously mentioned.
2	Pre-emptive replacement	• This is the preferred option, as a package of works has been identified through a series of site health and criticality surveys and review of site-specific inspection and test results. • These sites have been costed using costing templates which were provided for similar size and scope projects in GD1.
3	Pre-emotive rebuild	• This is the alternative to a replacement programme and looks at a full rebuild – a “whole systems” approach the E&I installation at SGN Offtakes and PRS’ • This is the “gold plating” option and Network E&I are of the opinion this does not represent best value for money for the end customer. • To maintain a safe and reliable system, the replacement scope of works is more suitable.

Table 11: Summary of CBA Results

NPVs based on Payback Periods (absolute, £m)								
Option No.	Desc. of Option	Preferred Option (Y/N)	Total Forecast Expenditure (£m)	Total NPV	2030	2035	2040	2050
Scotland LDZ								
Baseline	Replace on Failure	N	-2.97	-6.13	-2.49	-3.04	-3.49	-4.76
1	Pre-emptively replace Absolute NPV	Y	-2.38	-3.12	-1.60	-1.82	-1.97	-2.59
1	Pre-emptively replace NPV relative to Baseline	Y	-2.38	-3.12	0.88	1.22	1.52	2.17
2	Pre-emptively rebuild Absolute NPV	N	-3.09	-4.10	-2.88	-2.88	-2.88	-3.86
2	Pre-emptively rebuild NPV relative to Baseline	N	-3.09	-4.10	-0.40	0.16	0.61	0.90
South of England LDZ's								
Baseline	Replace on Failure	N	-2.42	-15.10	-4.51	-6.46	-8.04	-11.28
1	Pre-emptively replace Absolute NPV	Y	-6.03	-7.84	-4.34	-4.80	-5.12	-6.70
1	Pre-emptively replace NPV relative to Baseline	Y	-6.03	-7.84	0.17	1.66	2.92	4.58
2	Pre-emptively rebuild Absolute NPV	N	-7.77	-10.12	-5.59	-6.19	-6.60	-8.64
2	Pre-emptively rebuild NPV relative to Baseline	N	-7.77	-10.12	-1.08	0.27	1.44	2.63

8.2 Business Case Summary

This project is driven by the potential for loss of life following a gas release caused by low temperatures down steam of the pressure reduction valve. The loss of prolonged power to site could affect key systems on site such as gas pre-heating and telemetry, which monitors key parameters on site such as pressures, temperatures and flows. This option also allows for SGN to comply with key legislator requirements such as the electricity at work regulations and the dangerous substances and explosive atmospheres regulations.

Table 12: Business Case Matrix

	Pre-emptively replace	**Pre-emptively rebuild**	**Pre-emptively replace**	**Pre-emptively rebuild**
	Scotland		South of England	
GD2 Capex (£m)	2.38	3.09	6.03	7.77
Number of Interventions	9.00	9.00	26.00	26.00

Carbon Savings ktCO2e (GD2)	0.00	0.00	0.00	0.00
Carbon Savings ktCO2e /yr	0.00	0.00	0.00	0.00
Carbon Emission Savings (35yr PV, £m)	0.00	0.00	0.00	0.00
Other Environmental Savings (35yr PV, £m)	0.00	0.00	0.00	0.00
Safety Benefits (35yr PV, £m)	1.37	1.37	6.69	6.69
Other Benefits (35yr PV, £m)	0.00	0.00	0.00	0.00
Direct Costs (35yr PV, £m)	1.07	-0.15	-1.43	-3.58
NPV (35yr PV, £m)	2.44	1.22	5.26	3.11
High Carbon Scenario				
Carbon Emission Savings (35yr PV, £m)	0.00	0.00	0.00	0.00
High Carbon NPV (35yr PV, £m)	2.44	1.22	5.26	3.11

9 Preferred Option Scope and Project Plan

9.1 Preferred option

The preferred option is to pre-emptively replace the E&I equipment on site as it's the most cost effective solution and delivered all of SGN's legal requirements.

9.2 Asset Health Spend Profile

The preferred option considered for the RIIO-2 period is to pre-emptively upgrade the electrical, instrumentation and control assets and associated equipment as per Option 1 within the CBA.

Table 13: Spend Profile – Scotland

Asset Health Spend Profile (£m)					
Pre-emptively replace	2021/22	2022/23	2023/24	2024/25	2025/26
Scotland LDZ	0.48	0.45	0.44	0.49	0.52
South of England LDZ	1.24	1.16	1.17	1.17	1.29

9.3 Investment Risk Discussion

Table 14: Investment Risk Discussion

Risk Description	Impact	Likelihood	Mitigation/Controls
Budget	Over Spend	<=20%	As this workload is very varied and cannot be predicted, there is the risk that some projects may be a higher spend that requested (per site) in the EJP. However this risk is minimal as history (section 3.1 in EJP) shows that a number of projects will also be lower so overall the budget should balance to being neutral. If there are any failures which require an excessive amount (site rebuild) then SGN would raise this through the SGN Investment Committee before committing a spend and the major rebuild scopes have been captured in another EJP for that type of work.
Budget	Over Spend	<=20%	Network have not built in any risk/contingency costs for this works. SGN will package up the works to achieve the greatest discounts on design and materials
Budget	Over Spend	<=20%	SGN will use internal resource to carry out on site installation works (E&I Operations) where possible

Capex Sensitivity

Table 15: Sensitivity Results

	Scotland LDZ			South of England LDZ's		
	Low	Mid	High	Low	Mid	High
GD2 Capex (£m)	2.02	2.38	3.09	5.13	6.03	7.84
Number of Interventions	9	9	9	26	26	26
Carbon Savings ktCO2e (GD2)	-	-	-	-	-	-
Carbon Savings ktCO2e /yr	0	0	0	0	0	0
Carbon Emission Savings (35yr PV, £m)	0.0	0.0	0.0	0.0	0.0	0.0
Other Environmental Savings (35yr PV, £m)	0	0	0	0	0	0
Safety Benefits (35yr PV, £m)	1.4	1.4	1.4	6.7	6.7	6.7
Other Benefits (35yr PV, £m)	0.0	0.0	0.0	0.0	0.0	0.0
Direct Costs (35yr PV, £m)	0.9	1.1	1.5	-1.3	-1.4	-1.8
NPV (35yr PV, £m)	2.2	2.4	2.9	5.4	5.3	4.9

Project payback has not been carried out as part of this analysis due to the effect of the Spackman approach. For a cash-flow traditional project payback period please see scenario 4 of our Capitalisation Sensitivity table.

Network E&I believe the preferred option is pre-emptive replacement. For the purpose of sensitivity analysis, the following has been applied to the preferred option of pre-emptive replacement:

Low Case: SGN have applied a reduction of 15% CAPEX costs – this can be applied if SGN achieve greater than expected discounts on material purchase and also if greater efficiencies can be achieved in projects delivery that haven't already been fed into the costs – this would be process improvements and streamlining working practices to reduce mobilisation time on site.

Mid Case: no changes have been applied, this is the expected output required for the GD2 time period.

High Case: SGN have applied an additional 30% on the CAPEX expenditure, as this is believed to be the potential cost increase if SGN do not go to tender and achieve best possible market prices. This could also be impacted by political changes which may impact on resource availability or material costs. This increase in cost also allows for any issues in obtaining generic designs for the full volume of works or SGN not being able to delivery these projects efficiently due to internal processes which would increase contract labour costs.

Capitalisation Sensitivity

Consumers fund our Totex in two ways – opex is charged immediately though bills (fast money – no capitalisation) and capex / repex is funded by bills over 45 years (slow money – 100% capitalisation). The amount deferred over 45 years represents the capitalisation rate. Traditionally in 'project' CBA's the cashflows are shown as they are incurred (with the investment up front which essentially is a zero capitalisation rate). Therefore, we have developed scenarios that reflect both ways of looking at the investment – from a consumer and a 'project'.

The scenarios are summarised as follows:

- Scenario 1 - we have used the blended average of 65%, used in previous iterations of this analysis.
- Scenario 2 - we have represented the Capex and Opex blend for the two networks, as per guidance.
- Scenario 3 - addresses our concerns on capitalisation rates whereby Repex and Capex spend is deferred (100% capitalisation rate) and Opex is paid for upfront (0% capitalisation rate).
- Scenario 4 - this reflects the payback period in 'project' / cash-flow terms and provides a project payback.

We have taken a view of the NPV in each of the scenarios, with the exception of scenario 4, at the 20, 35 and 45 Year points, to demonstrate the effect of Capitalisation Rate on this value.

Table 16: Capitalisation Rate Sensitivity Results - Scotland

Scenario	1	2 SC	3	4
Capex (%)	65	46	100	0
Opex (%)	65	46	0	0
Repex (%)	100	100	100	0
Output				
NPV (20yr PV, £m)	1.53	1.58	1.43	
NPV (35yr PV, £m)	2.39	2.44	2.31	
NPV (45yr PV, £m)	2.82	2.84	2.78	
Payback	0.00	0.00	0.00	0.00

Table 17: Capitalisation Rate Sensitivity Results – South of England

Scenario	1	2 SO	3	4
Capex (%)	65	38	100	0
Opex (%)	65	38	0	0
Repex (%)	100	100	100	0
Output				

NPV (20yr PV, £m)	3.04	3.19	2.86	
NPV (35yr PV, £m)	5.34	5.26	5.44	
NPV (45yr PV, £m)	6.65	6.63	6.67	
Payback	3.00	7.00	0.00	9.00

Appendix A - Safety Instrumented Systems

Introduction
Across SGN, there are a few Safety Instrumented Systems (SIS) operating to ensure the safe delivery of gas to consumers. SGN have identified 19 sites with legacy instrumented safety systems which comprise of Instrumented Protective Functions (IPFs) that act as a safeguard to protect life, properties, and the environment.

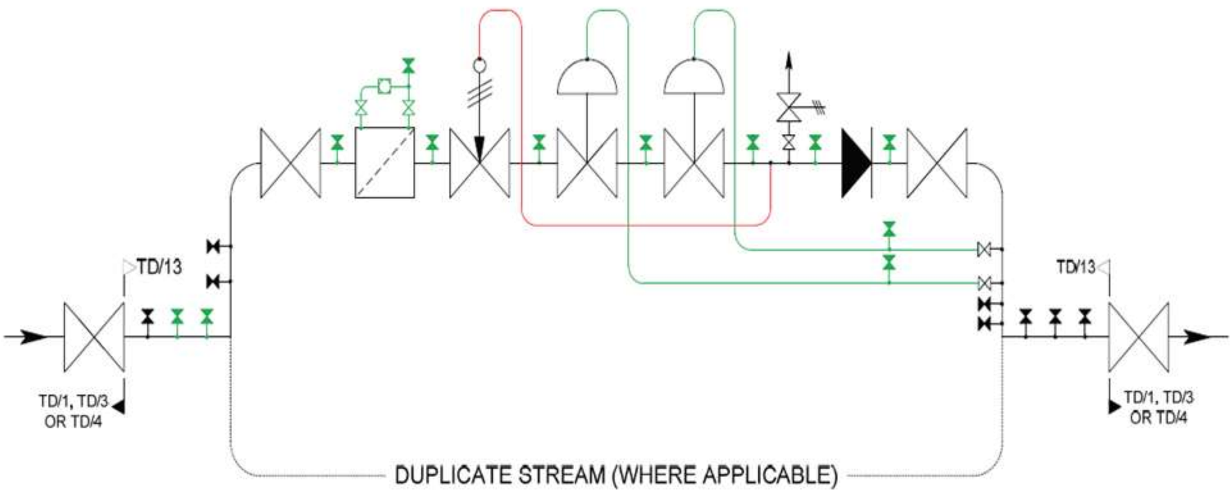
These legacy instrumented safety systems do not meet the management requirements IEC 61511, which looks at the lifecycle of the slam shut system.

General Background
Within the RIIO-1 control period SGN started a programme to replace the sensing pressure switch and actuating solenoid for devices with higher reliability inside standalone cabinets. SGN is also in the process of implementing the requirements of IEC 61511 to ensure we manage, maintain and assess these systems throughout their lifecycle, this has included the implementation of a generic proof test procedure for these sites.

Site Specific Background
The SIS considered for RIIO-2 control period focuses majorly on instrumented slam shut systems across 19 sites. These sites have similar mode of operation and requires a management plan to ensure all sites comply with the recommendations of IEC 61511.

Equipment Summary
The instrumented slam shut uses a pressure switch to sense the outlet pressure of the pipework, this via a relay energises a solenoid valve actuating a device that drives an actuator which closes the slam shut.

Figure 9: Typical IGE/TD/13 slam shut valve, monitor and active regulator



As indicated in figure 9, the regulators are adjusted such that it accommodates changes in pressure before the activating pressure of the slam shut system is reached. The slam shut is the primary protective device within the Safety Instrumented Function (SIF) Loop that protects the downstream pipe network onsite. The slam shut valve is designed to close once the setpoint is reached to prevent over-pressurisation downstream of the pipework.

Failure of the slam shut system to operate as intended may result to loss of gas or loss of containment which may result to a fire or explosion.

Redundancy Architecture of the instrumented slam shut system
Across SGN, slam shut systems are installed per stream such that if a stream slams shut the other stream can continue with the supply of gas to consumers. A telemetry system gives SGN Gas Control Centre (GCC) an overview of remote sites allowing operative to attend site to fix issues should they occur.

Problem Statement

Reasons for implementing a management requirement
The instrumented slam shut systems must comply to IEC 61511. This includes the management of the safety system which includes planning, project management, Functional Safety Assessment (FSA), competency, operation and maintenance, and control change.

SGN have assessed these legacy systems by consulting experts and conducting risk assessment using Layers of Protection Analysis (LOPA).

Not putting a robust functional safety management system in place is not recommended because the Health and Safety Executive (HSE) points to the functional safety standard as the pertinent benchmark for SIS.

Achievement Goals
SGN aims to manage the lifecycle of the instrumented slam shut systems such that it meets the requirements of IEC 61511. This will ensure that risks are As Low As Reasonably Practicable (ALARP).

Project Justification
SGN will ensure compliance with the recommendations of IEC 61508 and IEC 61511 by assessing and maintaining the instrumented slam shut systems. This includes maintaining asset records, identifying SIFs, identifying Instrumented Protective Functions (IPFs), carrying out Functional Safety Assessments (FSA), etc.

Narrative Real-Life Example of Problem
SGN have undertaken a gap analysis on the instrumented slam shut systems and so far, discovered noncompliance on 19 sites. A summary of the findings includes incomplete records of assets, no functional safety assessments, no management plan as recommended in IEC 61511 for the lifecycle of the slam shut systems, etc.

SGN risk being in breach of the recommendations of IEC 61511 and the Health and Safety Act etc. 1974 if a management process for all instrumented slam shut systems identified are not addressed as recommended in IEC 61511.

Spend Boundaries
The spend for this project will only cover the management plan that will ensure SGN SIS comply with the recommendations of IEC 61511.

Probability of Failure
The probability of dangerous failure (PFD_{1oo1}) (see equation 1) derived from IEC 61508 Part 6 Annex B was used to determine the failure rates for the instrumented slam shut system.

Equation 1Probability of Dangerous Failure for (1001) system:

$$PFD_{1oo1} = \lambda_{DU} \times \left(\frac{Ti}{2} + MTTR\right) + (\lambda_{DD} \times MTTR)$$

A typical IGEM/TD/13 Pressure Reduction Installation (PRI) across SGN with a telemetry system and an annual proof test interval will have a PFD of 0.03689. Further detail on the calculation is provided in table 12.

Table 18: Probability of failure

Pressure Switch		
Dangerous Undetected Failure Rate per hour (λ_{DU})	3×10^{-6}	
Test interval in hours (Ti)	8760	
Mean Time to Restore (MTTR)	8	
Detected Dangerous Failure Rate per hour (λ_{DD})	N/A	
Probability of dangerous failure (PFD_{1oo1})		0.01416
Relay and Power Supply		
Dangerous Undetected Failure Rate per hour (λ_{DU})	9×10^{-7}	
Test interval in hours (Ti)	8760	
Mean Time to Restore (MTTR)	8	
Detected Dangerous Failure Rate per hour (λ_{DD})	1.14×10^{-4}	
Probability of dangerous failure (PFD_{1oo1})		0.00486
Solenoid valve, Kinetrol actuator, Cameron valve		
Dangerous Undetected Failure Rate per hour (λ_{DU})	4.3×10^{-6}	
Test interval in hours (Ti)	8760	
Mean Time to Restore (MTTR)	8	
Detected Dangerous Failure Rate per hour (λ_{DD})	N/A	
Probability of dangerous failure (PFD_{1oo1})		0.01887
Total Probability of dangerous failure (PFD_{1oo1})		0.03689

Probability of Failure Data Assurance
The probability of failure data was derived from a LOPA study that was undertaken by SGN in 2015 for the instrumented slam shut system at Cobham PRI.

Consequence of Failure
Not meeting the recommendations of IEC 61511 will result to SGN being in breach of the relevant benchmark recommended by the HSE for SIS. The failure of the slam shut system could lead to loss of gas supply which may lead to fatalities.

Options Considered

Implement a functional safety management plan
SGN must put in place a management plan which fulfils the requirements of IEC 61511. This is the recommended approach by the HSE to demonstrate that risks are ALARP.

Do nothing

Doing nothing will be in breach of the management requirements of IEC 61511. SGN will be liable to huge financial penalties and reputational damage if an incident occurs.

Options Cost Details

The sum of £4,730,308.97 is the estimated benefit of introducing a functional safety management system and carrying out remedial works across 19 sites over the recommended lifecycle of the mechanical assets. The figures used in this calculation have been obtained from IGEM/SR/15 and the Greenbook methodology.

Table 19: Avoided cost table

Category	Numbers	Greenbook methodology figures	Maximum Tolerable Individual Risk	PRI pipeline depreciation period in years	Resulting cost
Fatalities	2	£16,170,000.00	0.000001	45	£1,455.30
Non-fatal incidents	1	£185,000.00	0.000001	45	£8.33
Major offsite incident affecting water supply, food chain, or housing for a period circa 1 month	1	£5,000,000.00	0.001	45	£225,000.00
Non-serious "nuisance" / odour incident	1	£50,000.00	0.01	45	£22,500.00
Total/site					£248,963.63
Total for 19 sites					£4,730,308.97

Associated costs:

Workstream	Cost/Site	No. Sites	Total Cost
Safety Systems Compliance	£10,000	19	£190,000

Business Case Outline and Discussion

The slam shut system is a safety critical device which acts as a safeguard to the downstream network. To ensure reliability of this system, SGN will ensure compliance to the recommendations of IEC 61511 by implementing a safety management plan.

Key Business Case Drivers Description

Table 20: Perceived values option 1 (implement functional safety management plan)

	Options	Perceived values	Consequences / Effects / Benefits
1	Implement functional safety management plan	£190,000	• This option fulfils the recommendations of IEC 61511 • This option reduces the probability of dangerous failures • This option will ensure functional safety assets are functioning as intended to protect lives, environment and properties
2	Do nothing	£4,730,308.97 avoided costs	• This option drives operational cost high • It leaves SGN and members of the public exposed to avoidable risk

Business Case Summary

Table 21: Business Case Matrix

	Options	Contributory factors
1	Implement functional safety management plan	• Best engineering practice • Avoidable risk reduced to an acceptable level • Improved working condition of the instrumented slam shut
2	Do nothing	• Bad working practice • Increased risk of a catastrophic failure • Non-compliance with the recommendations of IEC 61511 • Prolonged site downtime

Asset Health Spend Profile

Please refer to the main report – section 9.

Appendix B - Cost Breakdown

The below costs are based on previous project work within the GD1 RIIO price control period.

PRS Cost are as follows:

(Click to open)

Figure 10: Cost for Provan PRS E&I Upgrade

Commercial Confidentiality

Appendix C - Acronyms

Table 22: Acronyms

Acronym	Description
DMR	Dual Modular Redundancy
GCC	Gas Control Centre
GTMS	Gas Transportation Management System
HSE	Health and Safety Executive
IN	Integrated Network
LDZ	Local Distribution Zone
MTTF	Mean Time to Failure. MTTF is the ratio of the total time to number of units under test
NEP	Network Entry Point
NTS	National Transmission Site
RTU	Remote Telemetry Unit
IET	Institute of Engineering and Technology
ATEX	Atmosphere Explosive

Table 23: Applicable Standards

Standard	Description
IGEM/SR/15	Integrity of safety-related systems in the gas industry Ed. 15 with amendments December 2015 communication 1784
IEC 61131-3	Programmable Controllers
EAWR	Electricity at Work Regulation 1989
BS 7671	18th Edition IET Wiring Regulations
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations 2002