Investment Decision Pack
A9.14 – Condition Monitoring
December 2019

As a part of the NGET Business Plan Submission

nationalgrid

Engineering Justification Paper; Non-Load Related Condition Monitoring			
Asset Family	Condition Monitoring		
Primary Investment Driver	Other – links to monetised risk (lead assets), asset health (non-lead assets)		
Reference	A9.14		
Output Asset Types	- PD monitoring - DGA - Bushings - Sensor Integration to Assets		
Total Cost for RIIO-T2 Period	£22.2m		
Delivery Year(s)	2021-2026		
Reporting Table	C2.2A		
Outputs included in T1 Business Plan	No		
Spend Apportionment	**T1**	**T2**	**T3+**
	-	£22.2m	-

Contents

1. EXECUTIVE SUMMARY

This paper justifies the investment in condition monitoring during T2, a core aspect of asset management. We will spend £22.2m across four investments to replace condition monitoring equipment and enhance our capability by encompassing new condition monitoring approaches. This will allow us to renew existing capabilities which are reaching the end of their useful life. The four investments are:

- Rationalisation of our partial discharge monitoring of gas insulated switchgear (GIS) to provide consistent, flexible, targeted, state-of-the-art monitoring across our fleet of gas insulated substations at a cost of £[redacted]
- Targeted renewal of transformer on-line dissolved gas analysis capability that will reach end of life during T2 at a cost of £[redacted]
- Extending condition monitoring capabilities out to non-oil impregnated cables and through wall/floor bushings at a cost of £[redacted]
- Deployment of sensors on a range of assets to demonstrate the capability to adopt more intelligence-driven intervention strategies, based on advance analytics and measurable variables that define asset condition and performance at a cost of £[redacted]

The benefits from these investments will be partially realised within the T2 period and shall continue to accrue into T3 and beyond as we accumulate data associated with our assets and integrate it into our asset management approach.

For T2, our stakeholders have asked us to demonstrate good use of data and consider collecting data in a targeted approach, be clear on what the data is to be used for, use data proactively rather than after the event and change the plan based upon new condition assessment data. We have therefore separated out condition monitoring investments across different asset types and combined them into this one investment paper so that stakeholders can clearly understand our approach across the network, and so that we can identify and deliver condition monitoring synergies and efficiencies. There was no allocated allowance for condition monitoring during T1, but we have invested in our condition monitoring capability during this period, some of the benefits have been outlined in this paper.

We recognise that condition monitoring technologies will continue to develop between now and the end of T2 and to keep abreast of technological developments, where appropriate, we will consider the potential value of adopting alternative technologies that deliver the functional requirements described within the scope of this justification paper as they become available.

2. INTRODUCTION

Condition monitoring systems support informed asset management decisions that are dependent on asset condition data provided from monitoring systems to ensure that our network remains safe, reliable, operable and in service. Our asset management approach is to continually improve the understanding of our assets and this is achieved through the acquisition of an asset's condition data to identify deviations from the operating norm which in turn, can be translated into information to indicate the state of the asset. Repeatable and structured data collection and analysis supports the interpretation of asset condition or the prediction of asset failure. The provision of data from condition monitoring is therefore a key contributor to the assessment of asset failure likelihood across a range of timescales – from near real time to long term asset intervention planning.

The two highest areas of asset unreliability are during the beginning and end of life. At the beginning, during the 'infant' phase, defects not captured through the design, manufacturing and installation processes are likely to be identified which may impact network reliability if not managed appropriately. Defect rates fall over time during the 'infant' phase and this is followed by the useful period of an assets life where defects are minimal. The period towards the end of an asset's life is known as the 'wear out' phase where defects begin to increase again until ultimately, asset failure is reached.

Condition monitoring allows us to better manage assets during these two periods of their life. So, we can better understand how an asset is deteriorating, which allows us to intervene earlier than anticipated, where required, reducing the possibility of a catastrophic failure occurring. Or to delay interventions, where required, which reduces the amount of work required to maintain the same network reliability level. An example of the bath tub curve is given in the Figure below.

[redacted]

Figure 1 – Example of the bath tub curve

Condition monitoring employs various tools, techniques and processes to help measure and understand the likelihood of asset failure and thereby supports the optimal planning of interventions to reduce costs and maintain reliability when assessing network risk, the safety of people and the environment. Our stakeholders have told us that they wish for us to maintain our levels of reliability on the transmission system and therefore condition monitoring systems and processes, which feed into our asset decision making processes must be maintained and where appropriate, enhanced. It is a key part of our asset management philosophy that we must continue to deliver and exceed our stakeholders' expectations through the continuation to maintain, evolve and enhance our condition monitoring approaches.

Whilst the principle we apply to end-of-life assessment is consistent across all assets (considering the likelihood and consequence of asset failure to identify risk), the options and application of condition monitoring is asset specific, meaning that there is no singular technique that can address all asset types. For example, dissolved gas analysis (DGA) has proven benefits for the lifetime management of power transformers but has limited benefit when applied to bulk oil circuit-breakers due to differences in the deterioration and failure modes. Similarly, partial discharge (PD) monitoring is an effective way to monitor otherwise inaccessible insulation systems in gas insulated switchgear and cables but has little role to play for air insulated substations. NGET routinely deploy a wide range of such techniques in the day-to-day management of our assets. Examples of the condition monitoring approaches presently adopted are:

1. Removing the asset periodically from service to manually perform measurements, checks and deploy preventative maintenance tasks. Asset performance data is then stored at site with targeted data stored within systems.
2. Assessing asset condition periodically without the removal of the asset from service. This is achieved by visually inspecting the asset to identify wear of external components.
3. Targeted deployment of condition measurement and assessment techniques to assets showing signs of distress.
4. Online condition data acquisition through integrated sensor technology within the asset.
5. End of life ‘strip down’ analysis of failed-in-service/decommissioned assets to understand behaviour of failure modes in the remaining assets of the family.

This paper focuses on the deployment of new and the replacement of existing, aged condition monitoring systems. It presents the case for deploying the most technically appropriate systems, tools and techniques to obtain data to retain and enhance our ability to make effective asset management decisions. Specifically, this paper addresses online DGA for power transformers, PD monitoring for GIS and non-oil impregnated cables, the application of monitoring to through wall/floor bushings and the application of sensors to substation bay equipment.

3. RIIO-T1 Performance

In T1 condition monitoring allowances were included in the overall allowance in specific asset papers. Assets classes employed specific condition monitoring techniques in their T1 plans to deliver asset management benefits. For example, Supergrid Transformers used Online Dissolved Gas Analysis which has supported extension to the end of life of our transformers from 60 to 65 years, providing a value of £200m.

Our stakeholders have told us we should demonstrate good use of data, consider collecting data in a targeted approach, be clear on what the data is to be used for, use data proactively rather than after the event and change the plan based upon new condition assessment data. We have therefore pulled the condition monitoring allowance out into its own paper for T2.

Our proposed GIS condition monitoring data strategy is a good example how we are responding to this. The previous installation of permanent monitoring units has allowed us to collect sufficient condition data to confidently revise our monitoring strategy for T2. Our targeted approach will make use of transportable technologies to manage our population of GIS installations dynamically.

4. INVESTMENT DRIVER AND OPTIONEERING

The principle we apply to end-of-life assessment is consistent across all assets. To identify and prioritise assets in need of intervention we apply an assessment of failure likelihood and then the impact that any failure may have on the electricity system, the safety of people and the environment. These principles are consistent across the two principles evident in all our business plans, and are summarised as follows in Table 1:

Principle	Likelihood of Asset Failure	Consequence of Asset Failure	Risk is a function of Likelihood of an event and its consequence
Asset Health Index and Criticality	Scores assets according to their health. AHI1 to AHI4	Each asset is scored according to its system, safety and environment impact should the asset fail. The maximum score is used.	A Replacement Priority is output based on a matrix of AHI and Criticality score. Poor health assets in highly critical locations are identified for intervention over good health assets in locations with a low criticality.
Monetised Risk	Each asset has a probability of failure. This probability is arrived at by use of an 'End of Life Modifier'. This is a score that maps an asset to a place on a probability of failure plot, specific to each asset class.	For each asset failure event, there is a probability some other event will occur. These events have safety, system and environmental consequences that are monetised.	The probability of failure of an asset multiplied by the probability of an event with a monetised consequence produces the monetised risk of asset failure. As the same currency is used to define the consequences of asset failure, a whole network measure of risk is enabled as well as prioritisation between different assets.

Table 1 – Comparison of end of life condition assessment techniques

Condition monitoring plays a key role in our understanding of the Likelihood of asset failure across our asset portfolios and across a range of timescales – from near real-time to long term intervention (as outlined above). It employs various tools, techniques and processes to help measure and understand likelihood of failure, and thereby supports optimal planning of intervention when assessing risk and is therefore integral to the justifications across our business plan. Our stakeholders have told us that they wish for us to maintain our levels of reliability on the transmission system, and therefore condition monitoring systems and processes, which input into our asset decision making, must be maintained and, where appropriate, enhanced.

4.1 RII0-T2 Strategy

For T2 our stakeholders have asked us to demonstrate good use of data and consider collecting data in a targeted approach, be clear on what the data is to be used for, use data proactively rather than after the event and change the plan based upon new condition assessment data.

We have therefore separated out condition monitoring investments from across different asset types and combined them into this one investment paper so that stakeholders can more clearly understand our approach across the network, and so that we can identify and deliver condition monitoring synergies and efficiencies.

The investment driver, options and proposed solution for T2 are presented for the four condition monitoring investments below:

4.2 Partial Discharge Monitoring

High voltage assets rely on various insulation mediums to maintain the insulation strength between live parts and earth potential and thereby prevent flashovers. Examples include Sulphur Hexafluoride gas (SF_6), oil impregnated paper, cross-linked polyethylene (XLPE), epoxy resins and ceramic materials such as porcelain. Each of these has specific degradation characteristics for which we require appropriate diagnostic techniques if we are to effectively manage the affected assets and discharge the duties of a responsible asset manager.

One such technique is Partial Discharge (PD) monitoring - the detection and diagnosis of localised electrical breakdown within insulating materials under high voltage stress. This technique is globally recognised and proven as an effective way of detecting developing defects in insulation systems. The proactive detection of PD activity in an insulation medium allows us to make informed decisions and actions to be taken ahead of unplanned events such as failures which are costly to repair and disruptive for the network and its users.

PD monitoring requires asset specific tools and techniques to appropriately monitor our assets, which are outlined in the corresponding subsections below and demonstrated by the following case study.

4.2.1 Transportable PD monitoring – a simple case study

A simple case study to highlight where NGET has adopted this approach is the installation of the Hutton thyristor controlled series capacitors (TCSC's). This new (to NGET) technology was commissioned in February 2015 and unfortunately, in August 2015 a fault and subsequent fire developed in one of the valve houses on one of the TCSC platforms destroying the valve house and its contents. The equipment was under warranty and the OEM worked closely with NGET to identify the root cause and to take appropriate actions to modify and improve the design. The installation was subsequently out of service for 18 months while the OEM made the design changes, tested the changes and then installed the modifications to the already installed equipment and replaced the equipment that had been damaged during the fault. One of the main theories for the root cause was the build-up of moisture on optical fibres as they enter the valve house. To give added comfort that the modifications had addressed the main theory of failure and to provide a potential early indication if a similar fault was developing, transportable PD monitoring equipment was installed at the base of each of the installations for the initial 3 years. The PD monitoring has now been removed as early indications have suggested the modifications have been effective.

4.2.2 Gas Insulation Substations (GIS)

Technological developments in PD monitoring are enabling smaller, cost-effective and easily transportable PD monitoring systems to be deployed without significant compromise in their functionality compared with permanent installations. Our GIS PD monitoring strategy embraces the deployment of these systems.

Historically, state-of-the-art PD monitoring of GIS has been deployed as permanent computer-based PD monitoring and diagnosis systems at all GIS installations; an approach which we used selectively prior to T1 when our understanding of the performance of GIS insulation systems was developing. They provide maximum levels of monitoring throughout the lifecycle of the GIS regardless of the age, condition or perceived failure risk. They also minimise manual intervention to manage the monitoring equipment (OPEX costs). However, these systems are expensive, inflexible and require periodic replacement throughout the life of the GIS assets that they monitor. As these systems reach the end of their lives, our strategy is not to directly replace them with like for like systems, the strategy outlined below shall be adopted in T2.

<u>RIIO-T1 Context</u>

We have [redacted] sites classified as having GIS assets and which form part of our 400kV, 275kV and 132kV network. The age profile of our GIS assets is shown in Figure 1 below.

The gas insulation systems used within GIS are reliable over their lifetime, however, the highest likelihood of failure for GIS insulation is typically to be within the 'infant' and 'wear out' phases. When events do occur, they are difficult to manage due to the compact, integrated nature of GIS, which means that any repairs are very costly and require long outages which may impact on network reliability.

To manage GIS assets during these two periods of their life, we currently (RIIO-T1) use Ultra-High Frequency (UHF) PD monitoring techniques to detect potential faults within the insulation systems of our GIS assets. Our present monitoring capability is a mixture of permanently installed, substation-wide monitoring systems (mostly installed pre-T1 as part of GIS substation installations) and periodic monitoring using transportable equipment. This transportable equipment is delivered at sites without the permanent solution by external providers at a cost of £[redacted] p.a (Opex).

RIIO-T2 Option 1 – Targeted Deployment of In-House Transportable PD solution.

Under this option, we would adopt a common strategy for PD monitoring for all our GIS sites using a small fleet of in-house, transportable PD solutions. We would not replace ageing, site-wide fixed PD monitoring systems which would be retired as they reach their end of life. The information gathered from these fixed PD systems has enabled us to identify the 'infant' and 'wear out' phases are the key areas to target with monitoring as GIS remains reliable during the 'useful' phase which only warrants periodic monitoring. As such, we would target monitoring to focus primarily upon higher risk cases such as immediately post-commissioning (infant phase), assets with known/suspected defects, and those assets approaching their expected end of life (wear out), whilst retaining the capability to undertake periodic health checks for lower-risk, mid-life assets. Based upon our experience of such transportable equipment, we anticipate that [redacted] transportable detection units would allow monitoring coverage of the specified assets at an appropriate monitoring frequency. This would allow us to fulfil our ambition of undertaking regular assessments across our GIS sites – this will initially commence on an annual basis, with a view to optimising frequency as maturity of the process is established.

During T2, fixed, site wide PD solutions will be used only in exceptional circumstances or where a site-specific need-case can be proven.

T2 Option 2 – Replace Permanent Solution and Deploy Transportable PD survey solution

Under this option, we would replace existing fixed, site-wide PD monitoring systems as they come to the end of their useful life and we would buy in-house transportable equipment to monitor the balance of our GIS fleet as described in option 1. This option involves greater capital investment than option 1 and perpetuates an inconsistent approach to fleet-wide monitoring.

T2 Option 3 – Do Nothing

Under this option, we would not replace our fixed, site-wide monitoring systems as they reach their end of life and we would cease to deploy periodic monitoring of any sort across our GIS fleet. We would be less able to make informed and timely asset management decisions supported by data regarding the condition, interventions & lifetime of our GIS systems. In turn this would lead either to increased unreliability (undiagnosed defects resulting in faults) or potential inefficiency due to "over-intervention" to mitigate a perceived risk of failure.

T2 Approach

Option 1 - deploy [redacted] transportable PD detection, analysis units and associated connection equipment in T2 at a cost of £[redacted] (Capex). This cost includes procurement of the units and associated equipment to perform the test (e.g. coupling equipment). A total of [redacted] units will facilitate routine inspections across our regions, as well as providing capacity for managing exceptional circumstances at the 'infant phase' (fingerprinting) and 'wear out' at the end of asset lives in line with our asset management approach.

This approach is the most cost-effective way of retaining our ability to deliver PD monitoring of GIS whilst enhancing flexibility to target longer duration monitoring needs to those locations where it can deliver most benefit. Installing permanent systems previously has delivered value in reaching this conclusion when considering the PD monitoring strategy across the rest of our asset base and has allowed us to baseline our understanding of monitoring requirements for GIS technology. Without this initial investment to identify GIS remains reliable during the 'useful phase' of its lifetime, we would have been unable to evolve our GIS condition monitoring strategy to our current proposal.

Option 2 has been discounted due to additional cost required to replace the permanent installed solutions coupled with a transportable solution at a cost of £[redacted] (Capex). This accounts for replacement of [redacted] permanently installed solutions but would still require [redacted] transportable units to achieve the level of coverage outlined in option 1. Data from the installed solutions has confirmed GIS to be reliable and does not warrant continuous monitoring and does not provide any additional value when compared to option 1.

4.2.3 Non-Oil Impregnated Cables

<u>Background</u>

Cables have one of the longest Return to Service (RTS) times of any asset class when they experience a fault or failure. Where we can access cable sections, such as through tunnels routine inspections ascertain their condition to ensure their continuous reliability. For cables with oil-based insulation, we sample the insulating oil and use DGA to assess their condition. This technique is being reduced due to changes in modern cable insulating technologies being deployed on the system and therefore we need to develop a new condition assessment capability.

<u>RIIO-T1 Context</u>

During T1 there has been an increase of non-oil impregnated cables being installed onto the system. This prevents the use of DGA as a primary health indicator for non-oil impregnated cables, driving the need for alternative methods to assess the condition. This trend is due to continue in T2.

<u>T2 Option 1 - Deploy Transportable PD solution</u>

Non-Oil impregnated cable technologies such as XLPE necessitate new condition assessment techniques to gain insight into dielectric strength. For XLPE, insulation material sampling is not possible as a condition assessment technique during the life of the cable. PD monitoring is an established and effective technique to detect defects in XLPE cables and this option is to deploy this capability for post-commissioning checks 'infant phase', fingerprinting, periodic routine inspection during the useful life of the assets, defect management and 'wear out' end-of-life management.

<u>T2 Option 2 – Do Nothing</u>

If we do nothing to assess XLPE cable assets, it will either lead to increased unreliability (undiagnosed defects resulting in faults) or potential inefficiency due to "over-intervention" to mitigate a perceived risk of failure.

<u>T2 Approach</u>

Option 1 - transportable PD monitoring equipment which can be deployed across our fleet of XLPE cable systems at a cost of £[redacted]. In addition to our existing cable portfolio, during RIIO-T2 we are commissioning further cable assets as detailed in the Underground Cables investment decision paper. The £[redacted] will be used to establish a method of deploying a PD monitoring programme for these assets through their asset lifecycle as outlined in option 1.

4.3 Oil Sampling

<u>Background</u>

Performing routine oil sampling by offline DGA analysis remains the most cost-effective approach to managing transformers through most of their life when the risk of major problems is low. This involves taking oil samples from the asset at intervals, and assessing them in laboratories for indicators of asset condition. Oil samples are analysed to measure the concentration of gases which can indicate the asset condition. The concentrations of gases such as methane, acetylene and ethylene can be detected in the insulating oil and used to identify issues that could eventually lead to failure of an oil filled asset.

DGA techniques can be applied to the insulating medium within transformers and other fluid-filled electrical equipment like switchgear, cables and bushings break down to produce gases within the unit under conditions of abnormal stress such as electrical discharge or over-heating.

When the risk is elevated (e.g. when offline DGA has indicated a developing problem or when a transformer is believed to be very close to end of life), we can mitigate the risk and retain the asset in service, or ensure that we maximise the life of the asset by the application of online DGA. Online DGA involves the connection of a monitoring device onto an asset that measures the same diagnostic gases as offline DGA, at more frequent intervals, without the requirement for manual collection and provides near real-time results. These monitoring devices can be relocated on a needs basis to target the most critical assets. This capability enables proactive risk management for the associated assets. To maintain the level of network reliability, our use of DGA for managing transformers should be consistent into T2.

RIIO-T1 Context

The use of online DGA monitoring during T1 has enabled us to observe the condition of our transformers as we have been able to collect frequent condition data. By so doing, we have been able to improve the lifecycle management of our transformers, justifying an extension to anticipated asset life of transformers driving a value of £200m during T1.

Online DGA is a proactive system to manage the asset and supports the safety management of the asset whilst minimising the risk to personnel having to enter a Risk Management Hazard Zones to take manual samples of an asset that could be in distress.

T2 Option 1 – Replace Online DGA units

We adopted this technology before T1 and as described earlier, it has demonstrated significant benefits from extending asset lives. With a 7-10-year lifetime for the monitoring devices, we now need to replace our existing fleet of [redacted] online DGA units in order to retain this capability and to continue to deliver the benefits that have been included in our business plan.

T2 Option 2 – Do Nothing

The risk associated without this investment, our ability to optimise end of life decision making for transformers will be compromised and we would need to revise our business plans to reflect the higher risk associated with certain transformers that would otherwise be managed through our current condition monitoring approach.

T2 Approach

Option 1 - replace [redacted] online DGA units during T2 at a cost of £[redacted]. These versatile units are installed both on fixed location assets (to manage specific asset risks) and on redeployable trailers (to dynamically manage site risks when identified). The £[redacted] cost covers a proportion of both installation approaches, however the majority of replacements are anticipated to be in fixed locations. Offline DGA continues to be our policy as an effective condition monitoring technique and shall be supplemented with the online DGA capability where required to manage our population of large oil filled wound plant.

4.4 Through wall/floor Bushings

Background

Through wall/floor bushings provide a means of safely passing high voltage busbar connections through solid surfaces such as the external or internal walls of substation buildings. In some cases, they also incorporate the measurement functionality of instrument transformers adding to their criticality for operation and protection of the transmission network.

If not managed correctly, through wall/floor bushing failures are typically of a catastrophic nature which can result in porcelain dispersal across the substation with potential for consequential damage to personnel or adjacent plant. When assets are identified to be in poor health, to mitigate these risks, it is common to implement Risk Management Hazard Zones (RMHZ) around the asset.

As can be seen from the installation profile in Figure 2, many of the [redacted] through wall/floor bushing units, could be candidates for replacement in T3, based on anticipated asset life.

[redacted]

Figure 2 – Through Wall/Floor Bushing Installation Profile

<u>RIIO-T1 Context</u>

Our approach to managing bushings prior to and during T1 relied on periodic non-intrusive assessments to establish asset condition and inform intervention requirements, which usually resulted in the replacement of the bushing. This approach is not sustainable in T2 due to the quantity of that may require to be replaced based on their AAL.

<u>T2 Option 1 – Deploy Predictive Health Assessment Solution for Bushings</u>

To support the management of our through wall/floor bushing portfolio we will continue to evolve our bushing condition monitoring methodology to improve our predictive intervention capability.

This will be achieved through the application of condition monitoring techniques applied to a sample of the bushings, allowing us to better understand asset family condition and inform our investment decisions.

This will also support the output from our destructive asset health assessments that will be conducted during T2, to avoid wholescale bushing replacements in T3.

<u>T2 Option 2 – Do nothing</u>

We will be less able to make asset management decisions supported by data regarding the safety, condition, interventions and useful life of our bushings. This will lead either to increased unreliability (undiagnosed defects resulting in faults) or potential inefficiency due to “over-intervention” to mitigate the perceived risk of failure. Given the catastrophic nature of their failure mode, this can also impact on the safety of personnel and adjacent plant.

T2 Approach

Option 1 - further develop our bushings condition monitoring capability by developing alternative techniques that allow us to manage our aging bushings fleet, at an expected cost of £[redacted]. This mitigates the risk of changing all through wall/floor bushings exceeding their anticipated asset lives in T2 and results in a total expenditure of £[redacted]m for T2 as referenced in paper "A9.13 – Through Wall and Floor Bushings".

We shall continue to review and identify the most appropriate techniques available. In RIIO-T1 we have trialled an approach for through wall bushing management at [redacted] that used online test taps to avoid replacement where site access and network access are challenging. Activities to hone our approach will continue through the remainder of T1 for implementation in T2.

4.5 Integrated Sensors

Background

Intervention planning for long-lifetime assets such as transmission equipment requires knowledge of asset condition, deterioration and performance to be able to optimise the timing and scope of interventions. Historically, this relied on time-based interventions at periods derived from "manual" feedback of findings and periodic expert reviews.

All our asset types and families have measurable variables that defines their condition and performance. For example, monitoring the mechanical movement of circuit breakers between the closed and open positions is a key indicator of the asset's mechanical health. This performance data can be acquired by adopting and integrating data intelligence into our core systems through the exploitation of digital communication data analytics and integration technologies such as Internet of Things applications (IoT). This approach follows the UK government digital strategy of becoming a business making more informed data driven decisions[1].

Monitoring these variables as close to real time operation can provide indications of elements of the assets condition on a regular basis that would otherwise require gathering via routine asset inspection, and therefore allow more dynamic assessment of intervention priority. While it is not possible to do this for all condition drivers of all assets, trends can be established to further reinforce the respective asset health indices and determine intervention priorities.

Our asset management strategy drives us to continually improve the understanding of our assets. Gathering targeted data about our assets allows us to continually refine this assessment process – this ensures we make increasingly informed decisions, which may cause us to 'act' sooner or later on an asset. Whilst this approach may allow us to undertake less routine inspections and defer asset interventions/ end of life management as we continually hone our understanding of asset risk, it may also cause us in some cases to accelerate intervention on assets. However, in either case, it offers the benefit of further managing network availability to address those assets requiring priority intervention.

RIIO-T1 Context

The use of data acquisition from integrated sensor technology has seen benefits gained in the management of Transformers as highlighted in 4.3 through online DGA. No further deployment of online devices to asset families (such as Gas circuit breakers and disconnectors) occurred in T1.

T2 Option 1 – Extending Online Sensors Solution to Other Asset Families

Extend the approach of online monitoring (e.g. DGA for transformers) to other targeted circuits, bays and asset families to maximise availability. This will consider existing and new asset monitoring techniques when they become available that will provide benefits towards the end of T2 and into T3.

[1] https://www.gov.uk/government/publications/uk-digital-strategy/executive-summary

The expected benefits will increase the quantity and quality, while reducing the effort required to collect condition data to further enhance our understanding[2].

T2 Option 2 – Do Nothing

Our lifecycle management decision making capability will stagnate and future plans will be built upon the same approach as T1.

T2 Approach

Option 1 - deploy sensors and the necessary associated infrastructure on [redacted] circuits/bays representing circa [redacted] of the network at a cost of £[redacted] based on an average cost per circuit.

We will accelerate our learning from these pilot installations by choosing bays/circuits that are representative and more highly stressed mechanically, electrically or both such as those switching reactive compensation. We will also target operationally more critical circuits to demonstrate our ability to maximise availability. For T2 the plan is to spend £259.1m Cap Ex on CB and Bay interventions. For T3 our aim would be to reduce these costs through more informed data driven decisions.

To help inform or T2 approach we are currently testing on-line data collection across a select group of assets during the remainder of T1.

This is underpinned by stakeholder feedback 1st May 2019 that 'We need to consider collecting data in a targeted approach, be clear on what the data is to be used for, use data proactively rather than after the event.'

[2] CIGRE Technical Brochure - Obtaining Value from On-Line Substation Condition Monitoring, references benefits in management of Maintenance, Capital Investments and Risk Management/Reduction of assets pg154

5. EFFICIENT VOLUMES AND COST SUMMARY

A summary of the optimal condition monitoring investments identified by the optioneering and cost benefit analysis in the above section are presented here:

CBA ref	Asset Sub Category	Option
NGET_A9.40_GIS Partial Discharge_CBA	Partial Discharge Monitoring GIS	**Option Selected** Targeted Deployment of [redacted] In-House Transportable PD solutions and Tooling at a cost of £[redacted] **Rationale** Rationalisation of our partial discharge monitoring of gas insulated switchgear (GIS) to provide consistent, flexible, targeted, state-of-the-art monitoring across our fleet of gas insulated substations. To enable us to manage our GIS assets through their infant, useful and end of life to fulfil our ambition.
NGET_A9.40_Cable PD_CBA	Partial Discharge Monitoring Non-Impregnated Cables	**Option Selected** Deploy Transportable PD Solution at a cost of £[redacted] **Rationale** For cables with oil-based insulation, we sample the insulating oil and use DGA to assess their condition. This technique is being reduced due to changes in modern cable insulating technologies being deployed on the system and therefore we need to develop a new condition assessment capability.
NGET_A9.40_Online DGA_CBA	Oil Sampling	**Option Selected** Replace [redacted] on-line dissolved gas analysis units at a cost of [redacted] **Rationale** To support the management of high risk assets and our ability to optimise end of life decision making for transformers in our business plans
NGET_A9.40_Bushings_CBA	Through Wall/Floor Bushings	**Option Selected** Deploy Predicative Health Assessment Solution for Bushings at a cost of £[redacted] **Rationale** Without this capability, we will be less able to make asset management decision supported by data regarding the safety, condition, intervention and useful life of our bushings. This will support the investment decisions to be made for Through wall/floor bushings in T3.
NGET_A9.40_Integrated Sensors_CBA	Integrated Sensors	**Option Selected** Extending Online Sensor solutions to Other Asset Families at accost of £[redacted] **Rationale** Deployment of sensors on a range of assets (circa [redacted] circuits) to demonstrate the capability to adopt more intelligence-driven intervention strategies based on advance analytics and measurable variables that define asset condition and performance. Benefits are expected to be realised in T3.

In T2 we will therefore spend £22.2m to replace condition monitoring equipment and enhance our capability by encompassing new condition monitoring approaches.

6. KEY ASSUMPTIONS, RISK AND CONTINGENCY

We have built our business plan for our asset categories based on condition monitoring as described in this justification paper.

The expected benefits from the data captured from the integrated sensors will not be available until the end of T2 at the earliest.

Our asset management approach, which focusses on continuous improvement of our knowledge of assets, understanding and decision making, is recognised and appropriate.

7. CONCLUSION

We have explained the benefits of undertaking condition monitoring include the early detection of potential asset failures on the transmission network that enables NGET to formulate an appropriate intervention to address this issue. It is a key element to our whole life approach to asset management and enhances our capability to gather and act upon data pertinent to our assets above that available from inspections.

We have listened to stakeholder feedback that they wish for us to maintain our levels of reliability on the transmission system, to demonstrate good and targeted use of data, be clear on what the data is to be used for, and to use data proactively and have consolidated our T2 condition monitoring investments into this paper in an approach that ensures the continued safety, reliability and availability of the transmission network. Ceasing condition monitoring activities would reduce transmission network reliability whilst increasing the risk to equipment and personnel safety which does not align with the stakeholders needs.

We will remain proficient in applying condition monitoring techniques and to ensure this capability remains effective we need to maintain and invest in targeted condition monitoring, and we have set out the options and identified the most cost-effective investments.

We have identified the volume of existing condition monitoring equipment that will reach end of life by end of T2 and therefore require cost-effective interventions. This will be through targeted replacements. The volume for T2 is to replace [redacted] Online DGA units at £[redacted] and deploy [redacted] transportable PD monitoring solutions at [redacted]

We have also identified areas where we will improve our condition monitoring capability to continue to drive value through our asset management decisions in line with our stakeholder expectations during and beyond T2. An investment of [redacted] to establish a solution to acquire Through Wall/Floor Bushing condition data will be made. Also £[redacted]m will be invested to establish Cable Partial Discharge Monitoring. A further £[redacted]m investment in using sensor technology across [redacted] circuits of our transmission network will enable a step change in how we acquire asset operating performance data.

Condition monitoring is a rapidly evolving sector and where prudent, we will seek to introduce new tools and techniques to extend our present capabilities into areas where there is the potential for further added value in the management of network risk.

8. OUTPUTS INCLUDED IN RIIO-T1 PLANS

There are no outputs in T2 for condition monitoring that are included in our T1 plan. However, condition monitoring was embedded into specific asset classes.