Investment Decision Pack
A9.05 – Instrument Transformers
December 2019

As a part of the NGET December Business Plan Submission

nationalgrid

Engineering Justification Paper; Non-Load Related Instrument Transformers			
Asset Family	Instrument Transformers		
Primary Investment Driver	Asset Health		
Reference	A9.05		
Output Asset Types	• Current Transformers • Voltage Transformers • CTVT Combination Type		
Cost	£63.5m		
Delivery Year(s)	2021 – 2026		
Reporting Table	C2.2A		
Spend Apportionment (T2 schemes proposal)	**T1**	**T2**	**T3**
	£0.499m	£62.568m	£0.391m
Completion of T1 scheme		£0.087m	
Development schemes for T3			
Total	**£0.499m**	**£62.655m**	**£0.391m**

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1. EXECUTIVE SUMMARY

This report provides the justification for £63.5m of spend to replace [redacted] Instrument Transformers (ITs) over the RIIO-T2 period. The Instrument Transformers category includes Current Transformers (CT), Voltage Transformers (VT) and combination types (CT/VT). Instrument Transformers are the critical link between the primary switchgear and secondary systems and provide real time measurements to the protection and control devices which monitor the network status to detect fault conditions and trip circuit breakers to isolate faulty equipment. These assets are hermetically sealed devices, with no moving parts, however, they can have catastrophic in-service failure modes resulting in porcelain material ejected across the site and the asset catching fire. Therefore, the timely intervention is critical to maintaining safety and reliability of the transmission network, which is one of the key requests of RIIO-T2 stakeholders.

The instrument transformer intervention volumes are determined in line with National Grid's policy PS(T) EPS 12.11, through an asset replacement priority process. This incorporates the Asset Health Indices (AHI) and the Criticality impact on the network of the asset condition. The AHI is established from the annual asset health review which takes into consideration individual asset condition, known historic family type issues, design defects, anticipated asset life (AAL) and SF_6 leakers (where relevant). This identified [redacted] units which needed replacing during T1, which we are on track to deliver.

Cost efficiencies have been achieved over T1 and the average delivered unit cost of these assets has been reduced from [redacted] per phase to [redacted] per phase. This has been due to procurement efficiencies through expanding the supply market and changes in installation practices. There are no expected changes to the supply market hence we are confident that these costs will remain consistent for the RIIO-T2 period.

The total of [redacted] targeted for replacement in T2 equates to an average of [redacted] units (including emergency replacement) per year. We have high confidence that this is deliverable. In 2018 over [redacted] units were successfully replaced, proving our success in delivering these annual volumes of work. The volumes planned for the T2 period represent [redacted] of the total population of Instrument Transformers on the transmission network. The total volume also makes provision for the ongoing Polychlorinated Biphenyls (PCBs) asset removal and unplanned emergency replacements. The volumes planned for T2 are based on a well-established asset health and criticality assessment, which is updated annually. Only the assets that need replacing in T2 are targeted to be replaced. This volume maintains the overall risk position within this asset category.

All options were considered for IT interventions for the T2 submission, although only three are viable options for delivery. These are; do minimum, refurbishment and replacement. A cost benefit analysis (CBA) has been carried out for the viable options to establish the most economic and efficient solution. The CBA considers mitigation measures that would be required for the do minimum and replacement on failure options in the form of Risk Management Hazard Zones (RMHZ). The result of the CBA shows that replacement of instrument transformers is the best option that maintain network risks.

A consistent delivery programme must be maintained during T2 to ensure operability of the transmission network in safe, reliable and economic manner.

2. INTRODUCTION

Instrument transformers (ITs) provide the interface between the high voltage plant and the secondary equipment (protection, control, metering) on the transmission network. They are critical assets as they provide real-time readings of the voltage and current levels across the network. These readings are essential in the operation and control of the network and feed directly into the protection systems which autonomously trip HV equipment to isolate any fault that is detected. This function is a requirement of UK Health and Safety Law and is clearly set out in the Electricity at Work Regulations 1989. Most importantly instrument transformer readings ensure that any fault is detected and located so it can be isolated within milliseconds to minimise the danger to persons and equipment on the network.

There is a total of 20,231 IT's on the National Grid transmission network.

There are three categories of instrument transformers:

i) Voltage Transformers (VTs) – either wound VTs (WVTs) or capacitive VTs (CVTs);
ii) Current Transformers (CTs), and;
iii) CTVT Combination Devices – referred to as High Accuracy Metering (HAM) Units.

The photos below show two examples of instrument transformers:

Figure 1 - 400KV Hairpin CT at Cottam 400kV Substation

Figure 2 – Single Phase 132kV Capacitor VT at Grendon 132kV Substation

Potential Safety Implications of failure

Instrument transformer failures are typically of an explosive (called 'catastrophic') nature which can result in porcelain dispersal across the substation with the potential for consequential damage to personnel or adjacent plant. In order to quickly mitigate the potential harm to members of staff on site, Risk Management Hazard Zones (RMHZ), demarcated with cones and chains, are implemented around equipment with known family/design issues in order to control access into the equipment's proximity.

For example, a Reyrolle Hairpin CT catastrophically failed at Drakelow 275kV Substation on 4th January 2013 firing porcelain debris over a 25m radius. Following the incident investigation, over 900 RMHZs with a 35m radius were applied on all Reyrolle CTs with a similar design at all voltages. All Reyrolle hairpin CTs were re-prioritised and a plan was put in to place to deliver their replacement in order to eliminate the risk and remove the constraints that the RMHZ imposed. A list of all IT's with RHMZ in the plan for T1 or T2 is provided in appendix A of this report.

Figure 3 – Catastrophic failure of FMJL CT. The porcelain insulator exploded firing shrapnel across the site.

With 20,231 instrument transformers on the transmission network, and only a finite number that can be replaced per year, it is essential that there is an ongoing replacement programme to ensure units with deteriorating health are replaced ahead of failure, so the system can continue to operate correctly and safely into the future. Instrument transformers are critical in the operation and protection of the transmission network, resulting in potential safety issues if not replaced at the right time

3. PERFORMANCE AT RIIO-T1

1.1 RIIO-T1 Allowances

A total of [redacted] units were planned to be delivered by the end of T1. The planned breakdown of volumes across T1 is shown below. The volumes from 2013/14 to 2018/19 are actual volumes delivered, with the final two years being projected volumes.

Figure 4 – RIIO-T1 Delivered/Planned Volumes Per Year

We are in the process of confirming outages and resources for the final two years of T1, giving confidence in the delivery of the increased volumes in these years.

3.2 T1 Outturn Performance - Volumes

At the start of T1, several current transformers catastrophically failed resulting in porcelain dispersal across the respective substations. Following the failures, the delivery plan for all ITs was re-prioritised, to ensure that all CTs of the same asset family (FMJLs) were replaced to minimise safety impacts. The re-prioritisation of the T1 volumes ensured reliability and safety were maintained within the period despite this change in delivery plan.

Figure 5 shows a breakdown of the RIIO-T1 plan in more detail:

	RIIO-T1					
Instrument Transformers - Total	**T1 Allowances**	**T1 Actuals**	**T1 Forecast**	**T1 (all years)**	**Annual average**	**Annual av (first 6 years)**
Total volume						

Figure 5 – RIIO-T1 Delivered/Planned Volumes

*** This number excludes the units and of associated allowances which have been voluntarily deferred in agreement with Ofgem.**

3.3 RIIO-T1 Outturn Performance - Costs

At the beginning of RIIO T1, the installed unit cost was per phase. This was an average unit delivered cost which incorporated assumptions that flex the costs lower or higher depending on each installation. For example, a new IT may be smaller than the unit it is replacing, requiring modifications to steel structures and/or new foundations to ensure they fit and connect into the existing infrastructure on site.

There have been several initiatives during T1 that have reduced the delivered per unit cost of a 1-phase set of instrument transformers from an initial to an average of (not including development costs to ensure like for like comparison).

These include the following:

- The majority of the cost saving result from separate competitive tender events for CTs and VTs resulting in a lower ‘cost of equipment’ from new suppliers.

- Changes in technical procedures and specifications to provide cost effective solutions. We have reviewed the ongoing need for high frequency (HF) earthing on CVTs concluding in the removal of the requirement for CVTs to have HF earthing. This has saved [redacted] per CVT installation.
- Some cost savings have also been realised through a reduction in 'installation costs' as our internal teams become more efficient in delivery due to the repeatability of the work.

The revised [redacted] (1-phase set) delivered unit costs is based on current delivered average unit costs but does not include development costs of [redacted] per unit. Development costs include site visits, producing site visit reports, producing works information for tendering activities etc. which have been removed to ensure a like for like comparison with T1 is accurate.

Figure 6 illustrates the variation in costs across different installations for the three-phase set and the resulting average three phase set installed costs. The graph shows a representative sample of CTs. Using this sample of CT costs allows a comparable cost across all IT types.

Figure 6 - Delivered unit costs for 3 phases with average of the sample data

3.4 RIIO-T1 Performance versus Allowance

Our T1 allowance was for [redacted] per IT. We are planning to deliver [redacted] IT's, at a [redacted], with the benefits shared with consumers through the totex incentive mechanism. These savings are embedded in our T2 plans, with the [redacted] unit cost included within our baseline for all IT's in the T2 period.

Voluntary deferral of allowances

During the T1 period we have voluntarily deferred [redacted] of allowances, which relates to [redacted] instrument transformers. This is due to the results of forensic analaysis identifying less deterioration than forecast, hence requiring these assets to be replaced after the end of the T1 period.

Substitution of remaining IT volumes with Cyber Security

Due to increased levels of cyber security threats in recent years, and in the energy sector specifically, the Network Information Systems (NIS) Regulations were implemented in May 2018. In June 2019, the National Cyber Security Centre (NCSC) published a "Basic Profile" against their Cyber Assurance Framework (CAF) for all operators of essential services to comply with by May 2020, i.e. during the RIIO-T1 period. In order to comply with this requirement and wider general cyber-threat protection requirements to ensure the transmission network is secured from external threats, we have started to undertake additional Cyber related work to protect the network.

This has resulted in an increased forecasted T1 spend for Cyber, reported in the last Regulatory Reporting Plan, for which we did receive specific T1 allowance as the threat was not well understood at that time.

There are [redacted] instrument transformers that are not planned to be replaced in T1, due to asset health being better than forecasted and re-priotisation of the need. We have substituted the lower spend on instrument transformers, with the higher spend on Cyber. This has prevented a request for further allowance in T1.

4. INVESTMENT NEED

4.1 Investment Drivers

The two main drivers determining the intervention volumes for Instrument Transformers in the RIIO-T2 plan are deterioration on asset health condition, and SF_6 leakage.

These have been identified using the Asset Replacement Priority process described in Policy EPS 12.11. An asset with deteriorating health will be identified through the Asset Health Indices, which considers the asset's condition, family issues, assets approaching or beyond end of anticipated life (EOL).

The Anticipated Asset Life (AAL) of instrument transformers is 40-50 years. Many instrument transformers (c2,600 units) were installed on the network between 1965 and 1970 which was a significant spike in installation of new units. Between 1970 and 1990 the numbers of new instrument transformers added to the network was significantly less per year. This is one of the reasons why there was a large replacement volume during RIIO-T1 and why the baseline plan is less in RIIO-T2.

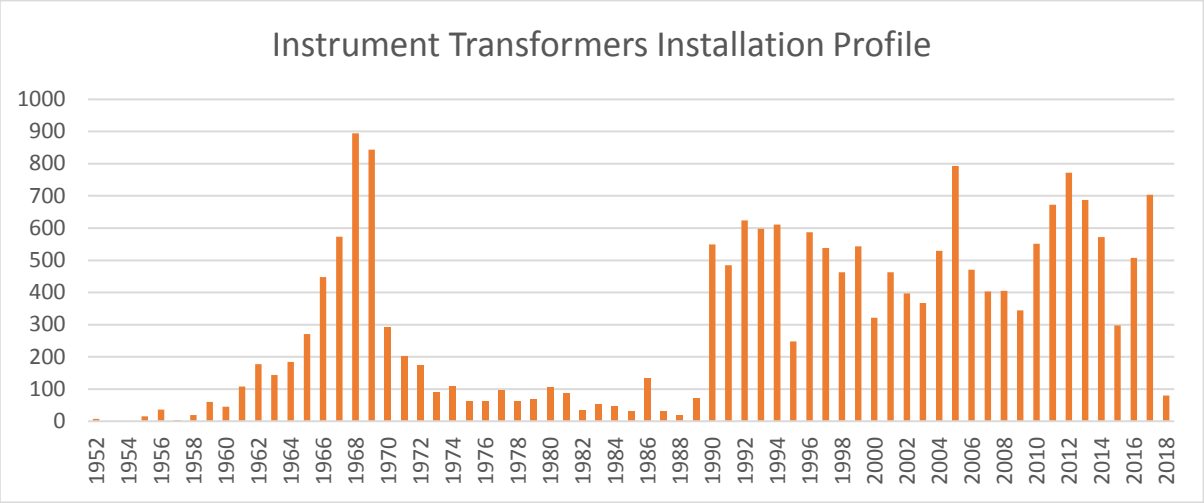

Figure 7 – Instrument Transformer Installation Profile by Year

In addition to the planned replacements, on average in T1 0.37% of the IT population failed prior to being replaced, this equates to approximately [redacted] of the planned replacement volumes in each year. It is therefore important to increase expected replacement volumes by [redacted] each year to cater for unplanned replacements.

The other key driver is units with poor or growing SF_6 leakage rates. This is determined through monitoring the volume and frequency of SF_6 top ups required on an individual asset base. There is a strong correlation between age and SF_6 leak rate. There are approximately [redacted] ITs that contain SF_6 on NGET's network. [redacted] units are in the T2 plan for replacement.

There is an additional driver from EU law to remove all assets containing Polychlorinated Biphenyls (PCB) from the transmission network when the opportunity arises. PCBs are a group of chemicals considered to be Persistent Organic Pollutants (POPs). The Stockholm Convention on POPs, which the UK Government and the European Union have signed up to, require that PCB contaminated equipment is removed from service by 2025 and destroyed by 2028. This impacts [redacted] Instrument Transformers on NGET's network, of which all are CVTs. This contributes to the total [redacted] VT replacements planned for RIIO-T2 ([redacted] of the total VT population).

The instrument transformer portfolio will continue to include scope for unplanned emergency replacements for situations where the sampling of the asset identifies it as being outside of normal parameters and in a state requiring replacement. We undertake forensic analysis of IT's removed from the network to understand family related issues. This provides crucial information and helps us to reduce unplanned emergency replacements by better understanding and taking appropriate actions on asset family problems that are identified during this process. This also includes volumes in a poor state identified during site visits. In 2018, a total of [redacted] units were prioritised under this category.

4.2 Approach to Estimating RIIO-T2 Volumes

This section sets out the approaches used to identify required interventions in the RIIO-2 period.

4.2.1 Annual Asset Health Review and Asset Health Index (AHI)

The annual asset health review takes into consideration equipment age and condition to determine the Asset Health Index (AHI) for each instrument transformer. The condition is categorised as defined by our policy (Technical Guidance Note TGN(E) 111), and replacement priority is also determined through policy (EPS 12.11).

The individual asset health index and associated condition related issues for candidate asset interventions during T2 are reported in Annex A9.20 – Non-Load Related Plan Build. Figure 10 provides a breakdown of the asset specific scores which are used to establish the AHI and any relevant criticality factors which in turn drive the asset replacement priority and intervention volumes.

Figure 8 shows how the AHI and criticality factors are used to create a replacement priority.

RP (years)	Description
0-2	AHI 1 instrument transformers with Very High and High criticality factors and AHI 2 instruments with Very High criticality factors whose replacement is within the next 2 years
2-5	AHI 1 instrument transformers with Medium and Low criticality factors and AHI 2 instruments with High criticality factors whose replacement is within the next 2-5 years
5-10	AHI 2 instrument transformers with Medium and Low criticality factors whose replacement is within 5-10 years
10+	AHI 3 & 4 instrument transformers that justify replacement after 10 years

Figure 8 – Instrument transformer replacement priority categories

The asset condition is determined through oil sampling (where appropriate) to analyse the dissolved gasses and moisture within the IT insulation, secondary winding deterioration of capacitor filaments, thermal and partial discharge. For units with SF_6, the leakage rate is a key factor. The assets are categorised against the intervention options ranging from immediate replacement in the case of a high probability of catastrophic failure to risk management and targeted replacement.

As mentioned previously, when replaced, selected assets are identified for forensic analysis to understand if the deterioration is linked to an asset specific failure mode or something which would affect a wider grouping of assets. This analysis helps to prioritise whether certain families of assets require intervention. This is a continuous activity which can result in a reprioritisation of previously selected assets should the failure mode be identified to be of a higher priority.

This selection process enables NGET to meet the stakeholder expectations for a safe and reliable Transmission Network. Through continually reviewing the selection of assets for intervention, the asset management principle of "Plan, Do, Check, Act" is employed and it is ensured that Assets with the greatest risk to Safety, System and the Environment are prioritised for intervention.

4.2.2 Condition Assessment

The design of instrument transformers precludes intrusive inspection and maintenance. Non-intrusive action at defined intervals is required to confirm condition. These activities include:

- Visual checks – oil leakage, corrosion, cracked or broken insulation, signs of electrical discharge, integrity of earthing, the terminal box, glands and external fittings as well as damage to gauges
- Audible noise – human detection of electrical discharge within the insulation of the instrument transformer
- Radio Frequency Interference – radio detection of electrical discharge within the insulation
- Thermography – detection of heat from increased resistive load on insulation
- Oil sampling for dissolved gas analysis and moisture content
- SF_6 loss, density and moisture level. The SF_6 leakage rate is measured by the amount and frequency of SF_6 top ups required in an asset.
- Secondary voltage checks for capacitor condition.

Diagnostic electrical testing can be employed (capacitance, loss angle and partial discharge tests) but there are issues in achieving consistent, accurate results during site tests due to atmospheric conditions and adjacent live circuits. These are generally conducted prior to an asset entering service (factory acceptance testing) and when an asset has been removed from service.

4.2.3 Identification of Asset Family Issues

Destructive asset health analysis (post-removal) and defect and failure history may identify asset family issues with a common failure mode that the non-intrusive checks (as above) may not have identified. This group may increase in numbers as more end of life destructive asset health tests are completed or more incidents on network occur leading to further investigations.

4.2.4 Instrument Transformers Anticipated Asset Life (AAL)

The Anticipated Asset Life (AAL) of instrument transformers is 40-50 years. Figure 8 shows the asset profile of instrument transformers based on the installed date. Since age is one of the factors taken into consideration, units installed during the 1970's and 1980's will form part of overall T2 volumes.

4.3 RIIO-2 Required Volumes

The T2 plan has [redacted] ITs planned for replacement, [redacted] of the total population (not including [redacted] emergency replacement). These units are selected based on individual unit condition, known family issues, anticipated asset life (AAL) and SF_6 leakage. The T2 volume also makes provision for units containing Polychlorinated Biphenyls (PCBs) and unplanned emergency replacements. In total, an average of [redacted] units (not including emergency replacement) are required to be replaced per year during T2.

An average of [redacted] of yearly planned volumes have been added to the T2 plan (1582) to cater for (i) the additional units identified during site visits, (ii) units resulting from the continuous condition monitoring and (iii) in-service failures of unplanned assets. The T2 plan has total of [redacted] assets in this category which is

[redacted] of total population on network. This aligns to failures seen during the T1 period. In year 2018/19, [redacted] units out of [redacted] were replaced under this category which is [redacted]

Figure 9 show the types of IT's requiring intervention, mapped to replacement priority.

IT Total	Includes [redacted] unplanned emergency replacements	[redacted]	
	CT /VT/HAM RP driven replacement		

CT Voltage (kV)	RP 0-2	RP 2-5	RP 5-10	RP 10+	Total
400	[redacted]				
275					
132					
<132					
Total					

VT Voltage (kV)	RP 0-2	RP 2-5	RP 5-10	RP 10+	Total
400	[redacted]				
275					
132					
<132					
Total					

HAM (kV)	RP 0-2	RP 2-5	RP 5-10	RP 10+	Total
400	[redacted]				
275					
132					
<132					
Total					

Figure 9 – breakdown of T2 asset by replacement priority

Figure 10 below shows a forecast of Instrument Transformers to be delivered each year throughout RIIO-T2. For deliverability purposes, the T2 annual volumes is the same volume as was replaced in the 2018/19 delivery year which provides solid indication on deliverability of plan and that the required outages can be secured. There has been continuous improvement on volumes delivered through out T1 by implementation of new systems and optimisation of the delivery plan maximising units delivered.

Figure 10 – RIIO-T2 Delivery Volumes showing target number to be delivered per year

5. OPTIONEERING

During the optioneering stage, various factors are considered when determining the options to be assessed. Each option is studied and a cost benefit analysis (CBA) is carried out to support the decision.

Due to the type and location of these assets, non-network and whole system solutions are not applicable for this asset type.

5.1 Options considered

5.1.1 Do Minimum

This option considers leaving all assets in service in T2 and only replacing them on failure in T2 with appropriate mitigation measures to maintain the required level of safety, and then an increased volume in T3 to return to the level of reliability requested by stakeholders. To manage an IT which is at high risk of failing, a Risk Management Hazard Zone (RMHZ) is setup around the asset(s) along with continuous condition monitoring. The RMHZ zone is a demarcated zone with cones and chains around the asset. It also includes management of access to the asset by staff. The condition monitoring is performed to continuously assess the condition of assets by taking oil samples. A RMHZ prevents any other assets (SGTs, CBs, Circuits etc.) from being accessed and maintained that are within the zone. This would prevent us from maintaining current levels of reliability within the T2 period.

5.1.2 Refurbishment (not viable)

Instrument transformers are hermetically sealed units containing electronic components with no mechanical moving parts that are insulated with paper and oil or SF_6 gas. Currently there is no refurbishment specification in place for IT's and it is not a practice within the industry to refurbish IT's for a number of reasons, such as the relative low cost of a new unit, lack of OEM support as the manufacturers of older IT's no longer exist. The inherent design problems that lead to catastrophic failures cannot be addressed through refurbishment. Based on these factors, no cost benefit analysis has been carried out for this option because it is not a viable option.

5.1.3 Replacement

Given the failure mode risk and relatively low replacement costs, replacement is a viable option for instrument transformers. This option removes potentially dangerous or environmentally harmful assets from the network in timely and cost-efficient manner making this an option which maintains safety and reliability.

CBA (NGET_A9.05_Instrument Transformer_CBA01) demonstrating the benefit of planned replacement over unplanned catastrophic failure (Do Minimum) has been included. This CBA accounts for the additional costs that would be required to make the substation safe and engage in clean-up activities results. It does not include any additional system impacts such as constraints to generators or the potential for a loss of supply to occur.

5.2 Options Assessment

5.2.1 Do Minimum

5.2.1.1 Costs

The costs included within the CBA for this option include additional costs for monthly oil sampling and for managing access due to the increase in RMHZ, and additional costs related to replacing [redacted] ([redacted] units) of assets expected to fail due to the 'do nothing' approach. This does not include system impact, constraint costs, impact of energy not supplied, public disruption, safety and environmental impact. This is due to these costs varying due to the location of these assets. Whilst there is also a potential for collateral damage, this has not been included within this assumption. This option assumes that a RMHZ is in place prior to asset failure.

5.2.1.2 Benefits

There is an initial cost benefit within the period due to the reduced replacement volumes. This does not provide a long-term benefit or meet safety and reliability standards or stakeholder requirements of maintaining current levels of reliability, demonstrating long term consumer benefit and complies with all relevant safety legislations.

5.2.1.3 Overall Assessment

This option was discounted based on the following:

- Stakeholders have informed us that this is not a viable option based on the above requirements.
- RMHZs prevent asset management intervention work on adjacent assets to be carried out
- This option increases network risk, reduces network reliability and leads to increased energy not supplied
- Environmental impact from catastrophic failure of the assets
- Not meeting our legal obligation under the Electricity Safety Act to minimise as far as practicable the hazards and risks to the safety of any person arising from the supply network

5.2.2 Replacement

5.2.2.1 Costs

The replacement of instrument transformers will predominantly be completed in-house by National Grid Electricity Transmission's Operational Teams as in T1 it has proven to be a cost-efficient means of delivery. It is also partly reflected in the unit delivered cost drop from year 2017 to 2018 as more units were delivered by internal operations staff. There are instances where it will be safer and more efficient to bundle the IT replacement with the scope of a larger project. For instance, if there is a contractor completing a circuit breaker (CB) replacement within a bay, then it would be advantageous to bundle the CT replacement that is related to the CB.

Scope & Assumptions

The typical scope of work for an IT replacement is similar across the sub-categories:

- Decommissioning, removal and disposal of existing IT (this includes gas removal of SF_6 where this is the insulating medium), disposal of PCB's.
- Installation and testing of new anchor bolts into the existing foundation,
- Procurement, installation and commissioning of new IT including new bus bars, connectors and secondary cables.
- Project Management, Design work, Drawing updates

For all of the replacements in the T2 plan, the following assumptions have been made:

- The existing foundation is fit for reuse and new anchor bolts can be set in the existing concrete
- New busbar, busbar connectors, secondary cables and fuse boxes are required. It is not viable to develop in detail each of the [redacted] IT replacements at this stage, in terms of the condition of these small components of an IT.

Key Assumptions, Risk and Unplanned Emergency Replacements

- The costs for replacement are based on actual delivered unit costs collated during the last 2 years of T1. This allows our recent good performance on cost to flow through and be embedded in our lower T2 unit cost.
- We have assumed that the installed unit price will not change during the T2 period. We have no evidence to suggest that there are any internal or external factors which may change the unit price.
- It is assumed that all the existing foundations for the replacement of instrument transformers are suitable for reuse.

6. T2 Unit Cost

The average cost of an IT replacement is [redacted]/phase across the IT portfolio based on recent T1 delivered unit costs, a reduction from [redacted] at the start of T1. This is an appropriate and comparable average cost as typically, the installed unit costs are reliant upon certain variables: CT, VT or HAM unit, asset type (i.e. SF_6 CT or Hairpin CT), voltage level and the number of units to be replaced (i.e. single-phase replacement or 3 phase replacement). Comparison to recent internal benchmarks is the most accurate way to set IT unit costs for T2, due to the repeatability of the work, and our experience in delivering these more efficiently. Based on our experience, we can be confident that the assumptions listed above are also accurate.

It is not practical to carry out site visits at this stage to confirm assumptions on [redacted] ITs. For this reason, an average delivered unit cost based on internal benchmarking is the most accurate method to set allowances for T2.

Total Cost for Preferred Option

Type	Volume	Cost
CT 400kV	[redacted]	£2.9m
CT 275kV	[redacted]	£20.4m
CT 132kV	[redacted]	£6.6m
CT <132kV	[redacted]	£1.3m
VT 400kV	[redacted]	£9.7m
VT 275kV	[redacted]	£8.8m
VT 132kV	[redacted]	£3.5m
VT <132kV	[redacted]	£0.9m
HAM 400kV	[redacted]	£0
HAM 275kV	[redacted]	£0
HAM 132kV	[redacted]	£1.2m
HAM <132kV	[redacted]	£0
Sub TOTAL	[redacted]	**£55.3m**
Emergency Replacement Units	[redacted]	£2.6m
Development Costs*	[redacted]	£4.7m
TOTAL	[redacted]	**£62.6m**

Figure 11 – Summary of volumes and costs for T2

***Development cost consists of site vists, site access from the operations team, compiling site visit technical reports , writing technical specification documents for suppliers, producing the relevant project execution planning documents as per our investment process for handing over to delivery entity, managing the portfolio changes and regulatory reporting throughout the period,

6.2.2.2 Benefits

This option provides a long-term lowest cost compared to the 'do nothing' option. The replacement of these assets also addresses SF_6 leakage, with the repeatability of the work allowing confidence in the unit costs being proposed, meets stakeholder requirements and removes the need for Risk Management Hazard Zones.

6.2.2.3 Overall Assessment

This option was chosen based on the following:

- This option maintains network risk and network reliability
- This option minimises the impact on the environment from catastrophic failure of the assets and meets Electrical Safety Act requirements.

Option	T2 investment (undisc, £m)	Total investment (undisc, £m)	NPV (£m, disc)	NPV inc monetised risk (£m, disc)
Do Minimum	-2.16	-2.70	-2.44	-2.44
Replacement	-62.599	-63.499	-55.739	-55.739

This does not include system impact, constraint costs, impact of energy not supplied, public disruption, safety and environmental impact. This is due to these costs varying due to the location of these assets. Whilst there is also a potential for collateral damage, this has not been included within this assumption. This option assumes that a RMHZ is in place prior to asset failure.

Instrument transformers are delivered through a variety of schemes. These include bulk schemes where only the ITs are replaced, plus lead asset driven schemes (switchgear, SGT, bays) where it is more efficient to replace the ITs whilst the replacement of the lead asset is taking place. RRP19 includes the costs for just bulk replacement schemes, but includes the volumes for bulk replacement and lead asset driven schemes which could result in an incorrect assumption of unit costs.

The following table shows a like for like comparison of bulk scheme instrument transformer costs in T1 and T2.

		RIIO-T2	RIIO-T1	RIIO-T2
Instrument Transformers - Total	**T1 (all years)**	**Forecast**	**Annual average**	**Annual average**
Total cost (£m)	56	62.6	7	13
Total volume	[redacted]	[redacted]	[redacted]	[redacted]
Cost per unit Volume	[redacted]	[redacted]	[redacted]	[redacted]

There is a slight increase in unit costs from T1 to T2 due to a different mix of transfomers types (CT, VT, CVT) and voltage across the periods. The [redacted] units mentioned above include [redacted] units that are held as contingency for emergency replacement, with the associated cost for installing the [redacted] included within the total costs for T1. Remaining volumes will be delivered through lead asset driven schemes. Both of the T1 and T2 costs include development costs for comparison.

7. KEY RISKS AND UNCERTAINTIES

7.1 Risks

7.1.1 System Access

System access (outages on the network) are agreed with the Electricity System Operation (ESO) in advance of the year of delivery. However, there is a risk that these outages can be cancelled due to operational constraints on the transmission or distribution network requiring relevant circuits to remain in service to maintain security of supply to customers. In such instances, the asset is re-planned for replacement later but can impact delivered volumes within a year. This report assumes a similar level of risk for system access as T1, as it is not possible at this early stage to request system access from the ESO.

7.1.2 Distribution Network Operator (DNO) plans

For ITs installed on an asset connected to a customer, the outage is dependent on agreement from those customers. In a similar manner to transmission network constraints, each DNO network has its own constraints and short-term re-planning is required due to operational issues on the DNO network. Although we have engaged extensively with each DNO for T2 and have an ongoing ‘business as usual’ engagement strategy with each DNO, it is too early at this stage to align business plans with each DNO. We have therefore assumed a similar level of risk for system access as T1.

7.1.3 Resource

Availability of key resource can be a constraint for delivery of all our work. We have well advanced workforce planning modelling which ensures our planned work can be delivered. As mentioned in 7.1.1 and 7.1.2 there will be short term changes to the plan, which are outside of our control. We have estimated the impact that this will have on our resource requirements, based on our recent experience of T1 to minimise the impact of this risk.

8. CONCLUSION

This report provided details about the assets involved, the types and their performance on the National Grid transmission network. It has detailed safety implications and historic catastrophic failures due to age and or design. A detailed activity schedule for T1 has been provided. The report details overall volumes on network, delivered volume in T1 and planned volumes for the remainder of T1 and T2. We have provided asset selection criteria, resulting in planned volumes and associated costs for T2.

The report covers options considered for interventions in T2 which include do minimum, refurbishment and replacement. Cost benefit analysis (CBA) has been carried out for the viable options to establish the best solution. The CBA considers mitigation measures that would be required for the do minimum (replace on failure) option in the form of Risk Management Hazard Zones (RMHZ).

It is demonstrated that the best option is the replacement of instrument transformers. Due to the relatively small cost of a replacement unit, this option best meets the requirements of our stakeholders, who have stated that our non-load activities maintain current levels of reliability, comply with all relevant safety legislation and demonstrate long term consumer benefit. Timely interventions on these assets maintains safety and provides the most economic option by eliminating the widespread network implications (and associated costs) of Risk Management Hazard Zones (RMHZ) and emergency works.

The instrument transformer portfolio will continue to include scope for unplanned emergency replacements for situations where the sampling of the asset identifies it as being outside of normal parameters and in a state requiring immediate replacement. The forensic analysis helps to identify family related issues and helps us to reduce unplanned emergency replacements by better understanding and taking appropriate actions on assets, and asset families that are identified during this process.

This report justifies the need to replace [redacted] units at a cost of £63.5m during the RIIO-T2 period. These are justified based on individual condition, known family issues, anticipated asset life and SF_6 leakage.

Appendix A – List of current RMHZ

List of current RMHZ around IT's.

This list has been redacted

Appendix B – Asset Listing

We have a complete asset listing for instrument transformers for T2 which we have not provided due to the size of the list. [redacted]

This list has been redacted