Draft Determination Supporting Document NGET - NGETAnnex Q12 DNV-GL Report

As a part of the NGET Draft Determination Response

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PENNY WISE – POUND FOOLISH: THE FALSE ECONOMY OF OFGEM'S RIIO T2 SPENDING CUTS

SAFER, SMARTER, GREENER

On 9 July 2020, Ofgem published[i] its draft determinations for the upcoming RIIO-2 price control. The draft determinations provide the first insight into Ofgem's proposed annual cost allowances for gas distribution and gas and electricity transmission companies to operate and maintain their networks. The headline message is that Ofgem is minded to[ii] reduce network companies proposed expenditure by 45% and 20%, on average, for the transmission and gas distribution sectors, respectively. The depth of Ofgem's proposed spending cuts is unprecedented, and it comes as no surprise that the draft determinations have not been well received by industry. Indeed, network operators have responded in unison expressing their disappointment, highlighting that the net zero agenda, the green economic recovery, and the future safety and reliability of energy networks are all in jeopardy – as well as hinting at a legal review as a possible course of action.[iii]

Ofgem considers it is acting on its primary duty to "protect the interests of existing and future consumers"[iv] and seeks to "deliver Net Zero at lowest cost to the consumer, while maintaining world-class levels of system reliability."[v] Tellingly, the area in which Ofgem proposes the greatest reductions is non-load related (NLR) expenditure for electricity transmission, covering expenditure to replace or refurbish assets to maintain network safety and reliability. This apparent contrast raises the question of whether the proposed spending cuts are indeed in consumers' best interests.

Of the transmission companies, National Grid (NGET) has seen its proposed NLR expenditure cut the most in both relative (approximately 61%) and absolute (approximately £2bn) terms. In its assessment of NGET's NLR plan,[vi] Ofgem typically cites a lack of evidence or engineering justification as the basis for its preliminary decision to deny funding of proposed expenditure. From a process perspective, Ofgem is right in that it relies on information provided by network companies to approve funding. However, even if Ofgem considers evidence is lacking at this stage, this does not necessarily confirm the absence of an underlying need for NLR interventions.

The gap between Ofgem and NGET at draft determinations has never been greater, and while Ofgem may be seeking to deliver benefits to consumers through spending cuts, it is in fact acting to the detriment of consumers. By denying NGET the necessary funding to invest proactively to ensure the safety and reliability of the transmission network at this stage, Ofgem is not just shifting this expenditure to future consumers, but is also passing on a higher level of network risk and associated costs, by steering towards a reactive, "fix-on-fail" strategy.

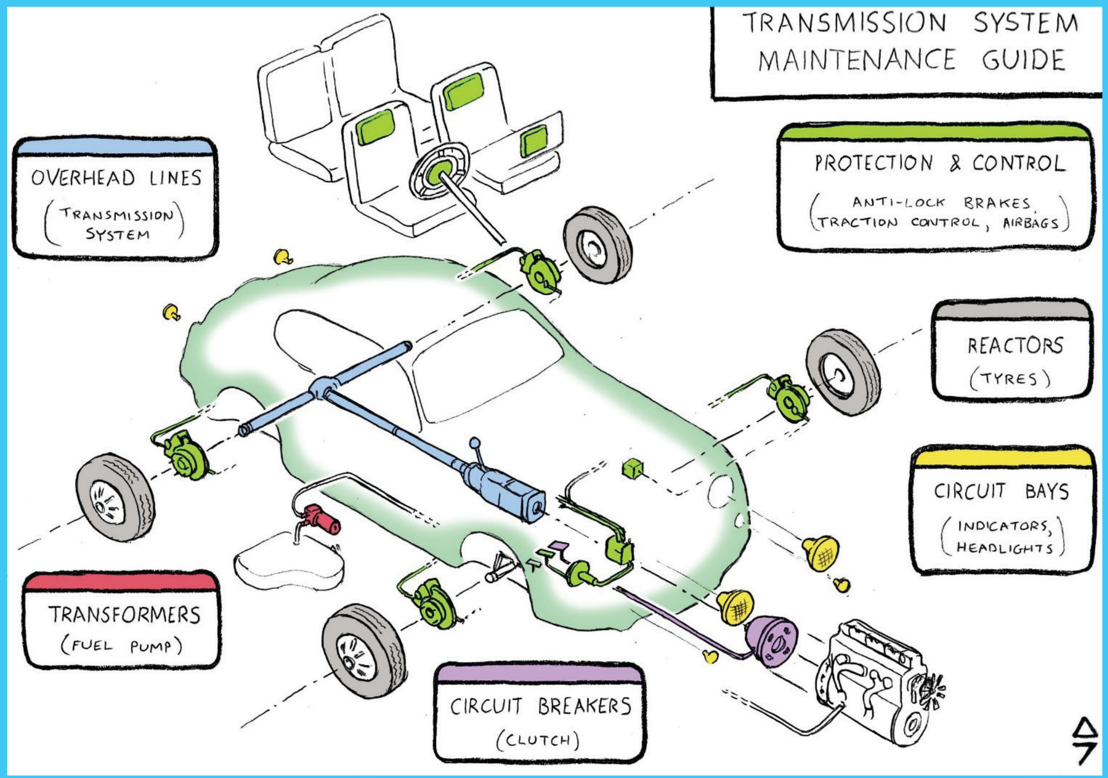
DNV GL has been commissioned by NGET to provide an independent, high-level view on the potential consequences of failing to invest in reliability, as well as to provide an independent estimate of the minimum required spend for NGET in RIIO-2 to maintain the current level of network reliability.

UNDERSTANDING RELIABILITY

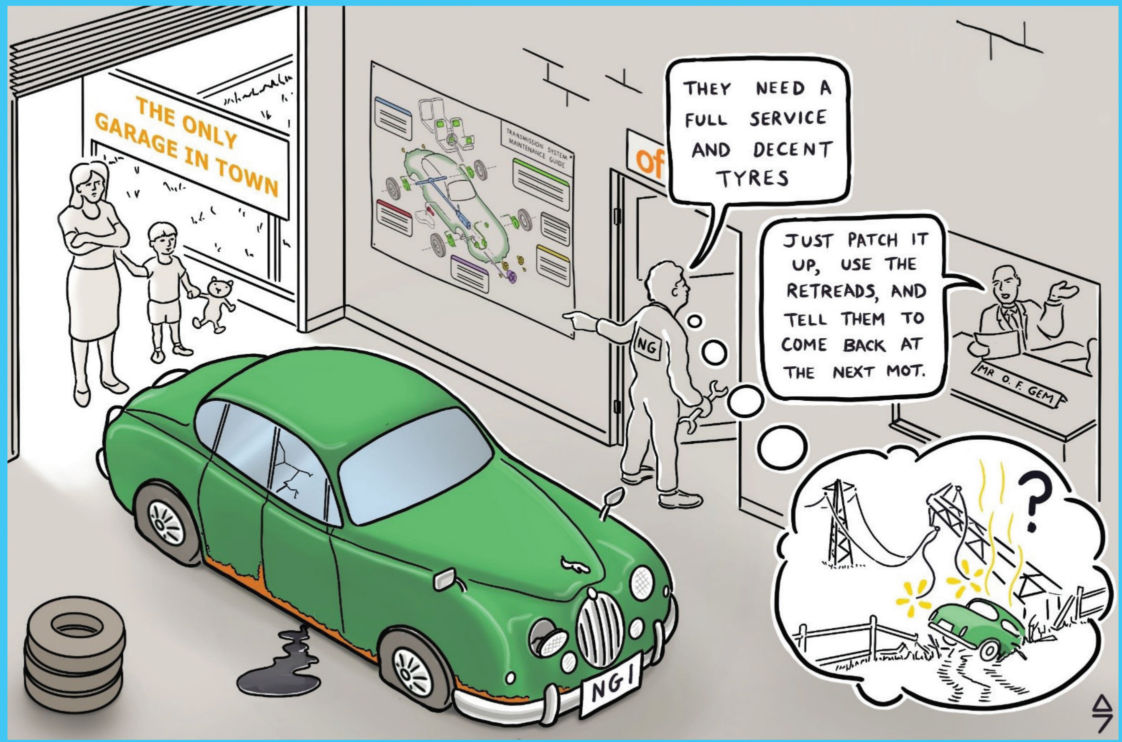
Electricity networks are the lifeline of our economy. They provide the means by which electricity is transported from the point of production to the point of consumption, and they are counted on to perform reliably by all of us, every day. Even the briefest of interruptions in service has consequences, ranging anywhere from mild inconvenience to vast physical and economic damage.

It is NGET's duty to develop, operate and maintain the transmission network in England and Wales so that it continues to deliver the reliable performance we are used to. However, our national transmission infrastructure is ageing (it was built largely in the 1960s and 70s), which increases the risk of assets failing and raises the challenge on NGET to maintain and replace critical components. Moreover, NGET has to ensure that the transmission network is resilient and able to cope with future changes in the delivery of the 2050 Net Zero agenda, such as the effects of electrification of heat and transport, flexibility and further growth in renewable generation. The journey ahead is long and far from certain, and failure to complete the journey will be costly.

It is imperative that NGET is prepared to undertake this journey in the best possible way. To understand what this requires, we have drawn an analogy with the maintenance of a car. The illustration below shows key transmission system assets reinterpreted in the form of a Haynes maintenance manual for a car.



Much like the transmission system, a car is a complex machine with a great number of components, and if any of these components were to fail, you may not arrive at your destination or you may even suffer an accident. This is why we have MOTs as periodic checks on the most vital components. It is especially important and sensible with an ageing car, to have the car checked at a garage before embarking on a long journey, making sure the airbags and brakes are functioning properly (much like the role Protection and Control equipment play in the transmission system), and that your tyres are at the right pressure (like the voltage control function of Reactors). Most of us would agree to spend a comparatively small amount to fix any issues and reduce the likelihood of having to pay a potentially much bigger price if the car breaks down on the journey. This is the central issue with the outcome of the RIIO-2 draft determinations: Ofgem is not currently allowing NGET sufficient funding to fix its car and ensure it will be able to complete the journey ahead.



OUR RELIABILITY ASSESSMENT

A transmission system needs to be robust and its individual assets need to be maintained to a minimum condition individually and collectively to maintain their capability and performance. Specific asset types are dependent on others to ensure safe and reliable power transmission, as well as the detection and clearance of faults and failures. Hence, the reliability of the transmission system, just like the strength of a chain, is in the weakest link.

In forming our views on the minimum level of investment required to maintain the reliability of National Grid's system, we have concentrated on four critical asset classes making up most (£1.77bn) of National Grid's funding request and in which Ofgem's proposed cuts (£1.47bn) are deepest.[vii] They are:

- Overhead Lines;
- Protection & Control;
- Circuit Breakers and Bays; and
- Transformers.

For each of these asset categories, we have reviewed information from NGET's December 2019 business plan submission, as well as information prepared by NGET as part of the Supplementary Evidence process, which will be made available to Ofgem. We have therefore relied on the same information that will be available to Ofgem in developing its final determinations.

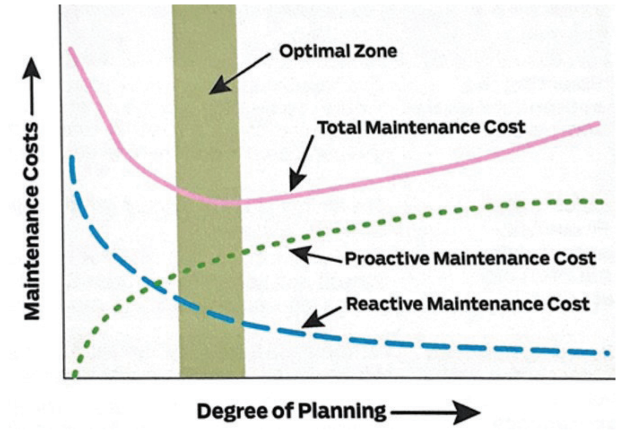
We have drawn on DNV GL's 90+ years as a global expert advisor to transmission network owners and operators and our deep knowledge of asset management in transmission systems and other complex high value infrastructure. This has enabled us to form an opinion of the interventions a reasonable and proactive transmission operator would need to undertake, given the current configuration and condition of assets making up the national transmission system, to avoid the significant consequences that transmission asset failure could cause.

We have specifically assessed available information from NGET on system resilience, asset criticality and condition, performance, deliverability and obsolescence to form a view of specific schemes or volumes that in our expert opinion are required to maintain an appropriate confidence in the reliability of the individual assets, their respective functions and the overall transmission network. In addition, we have considered how to manage the appropriate momentum in asset interventions to ensure that volumes of work moved into the future do not become undeliverable due to supply chain availability or capability, or due to lack of system access (required outages) to undertake the necessary works.

Ensuring the appropriate momentum is maintained is important from two perspectives; maintaining the skills and resources in the supply chain (so that the required work can be delivered in a stable way) and, ensuring that volume of assets in poor condition and requiring interventions is not greater than NGET's or the supply chain's ability to deliver the work (there must be sufficient resources, the ability to take outages on the system, supply of equipment, commissioning capability etc.). If the intervention volume is reduced to a level less than the deterioration rate of the assets, the number of assets in poor condition will increase over time as will the likelihood of asset failure with consequential impacts in terms of safety and performance.

In a complementary way, optimising the nature of interventions delivers performance and cost benefits by lowering the risk of asset failure and the resulting costs and consequences of that failure. And for some non-critical assets managing the risk through maintenance and risk management strategies reduces the cost to consumers. So, the asset managers job is to optimise the costs and benefits of proactive interventions and reactive response and costs of planning and managing them both over long periods of time.

Drawing again on the car analogy, a driver can carry on driving on bald tyres or not servicing the car, but the tyres will fail eventually with dangerous consequences and without regular servicing, components may fail causing more damage and far greater cost to repair than the regular servicing cost. Further, the car will be not be available as planned while it is in the garage for repairs. However, a driver may be content to accept holes in the carpets or upholstery and just patch that up rather than pay for the cost of a new seat. This proactive approach is considered international best practice by the Institute of Asset Management[viii], international standards such as ISO55000:2014 and the Institute of Public Works Engineering Australia (IPWEA – see figure).[ix]



We have considered the interventions required as those necessary to maintain a level of asset safety and network resilience that is satisfactory according to the information available and our engineering judgement. This does not represent achieving a target level of performance[x] but does represent the minimum level of interventions required on the asset portfolios we have examined. Our assessment of the minimum intervention level equates to between 5-10% on average of the assets we have considered.

We then validated our assessment by cross-checking with our experience from similar engagements, from which we know network operators replace between 5-20% of an asset population over a similar (5-year) period. On this basis, we would expect a reasonable and prudent transmission owner to make these interventions, given the criticality and condition of assets and taking into account the need to be able to deliver these and similar interventions over a longer period of time.

The table below summarises the outcome of our analysis, which is that Ofgem's proposed cut of NGET's £1.77bn funding request to £324m falls significantly short of what we believe to be the minimum required spend for these asset groups, which we place at £1.27bn.

	[redacted]	[redacted]		[redacted]		[redacted]	
		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The following sections summarise our analysis in each of the asset categories considered to arrive at this position.

OHL CONDUCTORS AND FITTINGS

Overhead transmission lines (OHL) are the core transport mechanism for bulk power from generation sources to distribution systems. Their function is not only electrical in transferring power, but they are also complex mechanical systems. To use the car analogy, OHL failure is akin to a broken transmission system: the car literally will not move without it, and there are multiple possible causes of failure.

We have examined high criticality overhead line routes in declining asset condition. Across conductors and fittings, we consider that there is sufficient evidence that the population requires intervention to maintain asset condition to a satisfactory level. We consider that without intervention, there is an increased risk of failure for these assets which could lead to the following consequences:

- Safety: The risk of conductors falling on people, structures or high-speed transport links, other electrical network equipment, housing.
- Reliability: Vulnerability to extreme weather events, multiple trips and even blackouts. In service failures during normal operating conditions can also be expected.
- Resilience: Ability of the system to withstand multiple trips caused by storms or ice accretion, particularly moving weather systems where 'cascade' tripping occurs resulting in energy supply disruption and ultimately system blackouts. Ability to deliver increased work volume in later periods will be hampered by the five-year starvation of the supply chain. Allowed volumes would support only a single supplier at half rations or less.

We consider that funding of the scale proposed in draft determinations will result in high volumes of degraded OHL assets left in service at the same time. In addition to living with increased risk, the work to alleviate the exposure to risk must be shown to be deliverable. The factors that impact deliverability include the following:

- The number of outages that can be tolerated without depleting system security levels;
- Sensitivity of construction work to changes to outage schedules especially delays of multiple years;
- The ability of contractors to respond to the need after a period of greatly reduced workload; and
- Proposed volume of conductor work slowly ramps up towards T3/4 required levels no step changes.

In light of these limiting factors, we believe that the bow wave of work volume that would have to shift between price control periods would be a risk to the ability to deliver in future periods.

We offer the following further considerations on the risks and potential wider impact of OHL asset failure:

- With a greater proportion of the OHL network carrying degraded components the tangible risk of mechanical failure increases as the health of the population is reduced. This risk will be manifested by a reduction in the strength of the component parts and will make OHL systems more vulnerable to unexpected high mechanical loads. Where degradation has been identified in routes proposed for refurbishment, the delay of intervention will increase the vulnerability to both the individual routes but, more seriously, system-wide events.
- Under fair-weather conditions, this strength degradation may not be a problem and may not manifest. The design of overhead line systems allows for a margin of strength. This margin is required for exceptional conditions associated with extreme weather or the local mechanical failure of the towers, foundations or fittings on adjacent (mechanically connected) towers.
- However, under extreme weather events (1 in 50-year events) there is the possibility of sustained high wind speeds or nationwide ice storms. Either event would lead to critical "wind sail" forces on the conductor or towers and therefore the catastrophic failure of component parts. When ice storms happen, ice may grow in layers on the conductor system and tower steelwork members creating an unusually large sail area to catch the wind. In this case, the conductor can dance around like a guitar string (or "gallop") and literally shake apart the towers that are holding it up. A conductor failure would result in a circuit trip and probably the dropping of a conductor to the ground creating a safety, mechanical and electric hazard to whatever the conductor hits.
- Weather events are widespread by nature, covering many hundreds or thousands of miles. The extent of the coverage can therefore subject entire networks to the same "stress event" within a matter of hours. The occurrence of an extreme weather event can therefore expose mechanical vulnerability across the entire network, with the consequence of multiple conductor, fittings or tower failures and multiple circuit trips.

We have reviewed information on circuit criticality, condition and location to determine a volume of assets that requires intervention: this involves those routes that carry significant transfers of power, long lines, where conductors over-sail major road and rail infrastructure (such as the M25) or poor conductor or fittings condition (such as with steel or aluminium degradation) or where there is a history of conductor oscillation (or "galloping"). We have also considered the impact on deliverability in future price controls if a bow wave of work is deferred into the future as the run rate needs to be maintained to at least the level of T1 to reduce the risk that the number of interventions required exceeds the ability of the supply chain or the system to deliver. [redacted]

Based on the asset condition evidence we have reviewed, and taking account of the future deliverability risks as well as potential wider impact from OHL asset failure, we consider [redacted] circuit kilometres of conductor and fittings driven OHL interventions, respectively, at a cost of £449m, is the minimum requirement to ensure network reliability is maintained.

PROTECTION & CONTROL (P&C)

There is a complex chain of interdependent assets working together to enable bulk energy transfer over the transmission system. Overhead lines, cables, transformers, switchgear and civil assets needing to function and perform on a 24/7/365 basis. System protection and control assets ensure the safety of personnel, assets and the system to deliver energy, by reliably removing faulty equipment from service whilst not affecting system stability. It also allows the reconfiguration of the network to accommodate planned work and optimise resilience and power flows. Perhaps equally important are the enormous developments that P&C assets have undergone over the past 20 years where integration of P&C functions and complex processing allows faster fault detection and more flexibility in reconfiguring networks.

In our car example, P&C equipment would be like the Anti-lock brakes (ABS), stability control and air bag systems, constantly monitoring multiple inputs and taking immediate action to keep the car and passenger safe in an emergency. Nobody should start a car journey if there are signs that the airbags and brakes might not be in working order. Moreover, everyone knows there are now more computers in a car, each of which is individually more powerful than the entire system supporting the 1969 Apollo mission that landed on the moon. The life of these computers will be shorter than that of the engine block and is effectively a black box (like a SatNav where the software is updated periodically and every few years you buy a more up to date, faster one).

The majority of the UK power system was designed and built 60-70 years ago. Protection systems at the time were largely of an electro-mechanical technology, over the last 40 years there has been a steady progression to solid state electronics and then in the last 20 to 30 years micro-processor technology. Electro-mechanical protection was relatively simple and robust with asset lives of up to 60 years, modern digital technology asset lives are as short as 15-20 years. The effect of this and the historical population profile means that underlying replacement rates need to increase as time passes.

Protection and control systems are the eyes and ears of the network and are required to operate quickly and accurately to protect plant and personnel, and crucially to maintain the stability of the transmission system as the nature of generation and demand connecting to it changes its characteristics, interacting more with the transmission system rather than being self-regulating (i.e. active distribution networks and the penetration of asynchronous generation with power electronic control systems). The argument for automation and integration of new technology standards such as IEC61850 is clear, and the benefit will be realised as greater integration is achieved as asset are replaced and refurbished to modern standards enabling greater operational flexibility, countering cyber threats and reducing asset maintenance needs.

Our assessment of appropriate spend for P&C is based upon the ability to deliver a portfolio of replacements across the identified P&C subcategories and prioritising subcategories according to their relative importance in protecting the system and delivering critical control functions. Failure to invest in timely replacement of P&C assets may have the following serious consequences:

- Safety: Protection is the primary method of triggering high speed electrical isolation in the event of a fault to protect the public, operators and equipment (e.g. a live OHL conductor touching the ground, overheating transformers (fire risk)).
- Reliability: Deteriorating performance as P&C systems exceed their expected asset lives and are largely unsupported by original equipment manufacturers (OEMs) and 3rd party suppliers. Preventing disconnecting faulty equipment before it fails allows recovery by planned intervention. Disconnecting overloaded equipment prevents consequential failures and cascade trips, and preserves life of other assets (e.g. transformer, cable and conductor thermal cycling).
- Resilience: Faulty or maloperation of protection equipment can leave circuits permanently switched out during a storm, reducing the network's resilience to other trips (overloads, voltage excursions and instability). In a widespread storm failure or maloperation can split the system, resulting in cascade tripping, generator trips and disconnection of demand. The ability to deliver increased work volume in later periods will be hampered by preventing the build-up of a sufficiently developed supply chain to handle future volumes.

As with other asset classes, we consider that the bow wave of work that would shift to subsequent price control periods would risk the deliverability of future required interventions if the draft determination volumes are applied and, given NGET's anticipated increase in volumes for T3 and T4, this is a problem that will only worsen so addressing the volumes now in T2 is essential. The ability to deliver projected volumes for RIIO-T2 is already tight, and although an assessment of resourcing indicates the RIIO-T2 programme is deliverable, the dependence on outage programmes is evident and will affect deliverability as the inevitable variations from planning manifest themselves.

As such, we consider [redacted] assets form the critical minimum to the network to manage poorly performing assets from the network and address the impending effects of obsolescence on the maintainability of P&C asset families that have been identified for replacement and refurbishment. This volume involves fast-acting primary protection and control systems, such as feeder, busbar, and mesh corner protections.

In addition to the key role of fast primary protection, we have taken into consideration the need for renewing back-up protection where it is not possible to replace primary protection. Over and above the critical minimum volume of [redacted] assets, we consider a further [redacted] assets should be delivered based upon reported RIIO-T1 run rates and we advise that this volume is required to reduce a continuing and accumulating backlog of replacement across the protection and control subcategories. The net result of our assessment is that [redacted] assets are excluded from NGET's original plan on the basis of not being deliverable due to an unmanageable run rate or not being as critical to maintaining reliability.

Our overall assessment is that critical assets and assets that can be delivered in this price control should be pursued, totalling [redacted] interventions at a cost of £401m, applying our estimate of unit costs for P&C assets
[redacted]

CIRCUIT BREAKERS AND BAYS

We have taken a dual approach to form our view on circuit breaker and bay assets: a view on asset health and criticality from information we have received from NGET and Ofgem's draft determinations, as well as an empirical approach using our experience to determine likely circuit breaker replacements and the consequential opportunities to replace and refurbish bay assets associated with them.

High Voltage Circuit Breakers protect electrical circuits and equipment (such as transformers) from damage from overloads or short circuits or excessive voltages, functioning as an automatic switch that interrupts current after a fault is detected. The circuit breaker is triggered by the protection equipment and works like a fuse to break the current. The circuit breaker is like the clutch in a car, immediately disengaging the engine from the transmission: a faulty clutch means that a problem with the engine could have wider impact for the car either stopping it dead or accelerating it into more danger.

Bay assets may not appear as crucial to the protection of the network in fault situations. However, disconnectors play an important part in the isolation of faulty equipment from the system and then re-connecting demand. They are integral to reconfiguring the network to manage power flows and provide network flexibility, and therefore play a vital part in network operation. They are also important in black start events directing power flows during re-energisation.

Earth switches play an important role in the safe maintenance of a transmission system, isolating items of equipment for maintenance or replacement work. Reducing reliability means reduced access for maintenance (because of the inability to take secure outages), higher duty on remaining equipment, and the potential for further deterioration in the primary equipment. This will lead to further unreliability, requiring more interventions, which cannot be made because of deteriorating health of safety devices such as earth switches. This is an example of 'the spiral of decline" that can face any asset manager and which a prudent one avoids. Bay assets are therefore highly critical in maintaining demand and protecting plant for certain fault situations.

Using the car analogy, bay assets are like the indicators or headlights, or the locking wheel nut key: they do not perform a primary purpose such as the brakes or tyres, but do play a vital role in safety to avoid crashes by lighting the way or indicating intentions to other road users, and are essential to maintenance where changing the tyre will need a functioning key to take off the tyres.

The potential consequences of underinvesting in Bay assets, which would result from funding levels in the draft determinations, could involve the following:

- Safety: Primary method of disconnecting overloaded or faulty equipment from the system rapidly, preventing cascade asset failures and injury.
- Reliability: Disconnecting faulty equipment rapidly before it fails allows planned intervention, disconnecting overloaded equipment prevents consequential failures and cascade trips, and preserves the life of assets (e.g. transformer, cable and conductor thermal cycling). Rapid circuit breaker and protection performance is becoming increasingly important in lower inertia, less stable networks to prevent instability and multiple tripping.
- Resilience: Ability of the system to detect and remove multiple circuits or assets from the system rapidly.

Our analysis finds that circuit breaker volume allowances in the draft determinations are both reasonable and consistent with the information provided by NGET, and we have therefore adopted the draft determinations volumes but applied our assessment of unit costs, which are around 8% higher on average than NGET's assumptions.

For bay assets, we assessed information on the volume of assets in asset health categories, which we categorised broadly into poor (16%), average (59%) and adequate (25%). We also assessed the criticality of assets and derived our recommended volumes from the population of assets that were in poor condition or were critical assets (39%) (such as bus section, bus coupler and mesh corner disconnectors and earth switches). Of the assets that were in average condition and not of a high criticality, we allowed for a volume that reflected a population that would deteriorate and would require an intervention within five years. We assessed this volume to be deliverable, and it maintained a more constant volume of work through price control periods.

We compared the results of these volumes against a simple volumetric model of number of bays and average assets per bay and an average unit cost [redacted] XXXX) as a sense check to the more detailed analysis outlined above. On this basis, we would recommend a cautious approach whilst more information is developed on failure modes and probability of failures, and we consider intervention in [redacted] CBs and [redacted] Bay assets at a cost of £215m to be a minimum requirement.

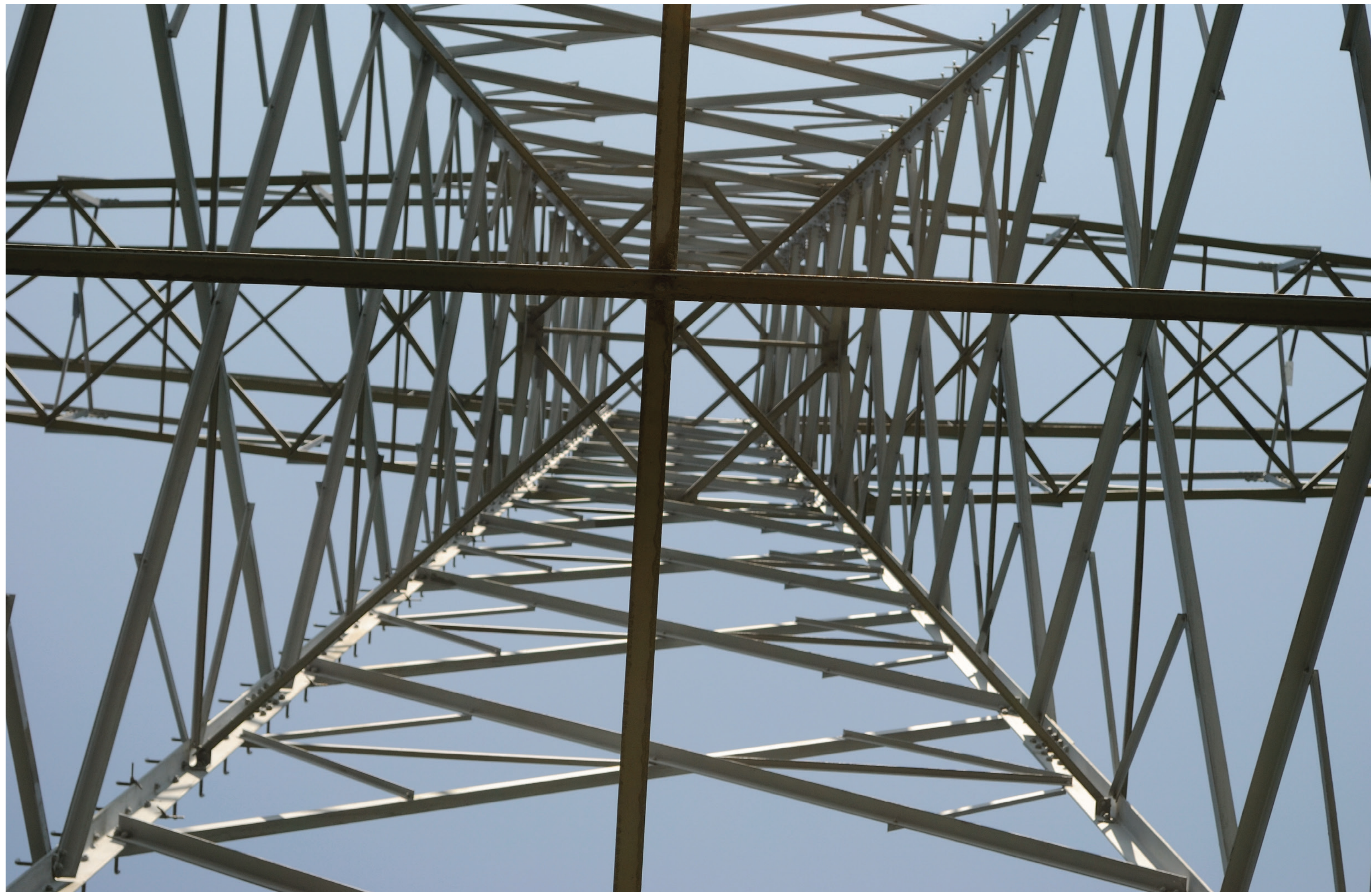
SUPER GRID TRANSFORMERS, STATIC COMPENSATOR TRANSFORMERS AND REACTORS

Transformer and Reactors manage power transfer across different voltage levels as well as helping to maintain the correct voltage on the system, so that industry and consumers' appliances and equipment operate correctly. Transformers are like the fuel pumps in a car, transferring fuel to the engine: if the fuel pump fails the car will run for a bit but will shortly stop. Reactors help maintain the right voltage levels, like air in car tyres. Without voltage control, we cannot move power around the system, and if the voltage is not within the right range the system can become unstable or even collapse. A malfunctioning reactor is the equivalent of taking your car onto the road without the tyres being properly inflated: steering and braking the car would be adversely affected, the journey would be slow, and the likelihood of a puncture would increase. Annex 6 of the Highway Code tells us to check our tyre pressure every week before any journey.[xi]

Super Grid Transformers (SGTs) are a mature technology and rarely fail catastrophically, but switching off a transformer automatically before it fails catastrophically often results in a loss of supply. Maintaining the safety from transformer failures is in large part due to modern protection and control systems, which will be required to be in good health to protect SGTs. Deteriorating transformers are identified through condition monitoring and from monitoring alarms and protection which detect assets starting on a rapid deterioration curve. Ofgem's proposed funding levels for transformers and reactors can lead to the following potential consequences:

- Safety: Large stored energy which can be catastrophic in failure with explosion and fire.
- Reliability reduction: Not replacing transformers in poor condition in time increases network risk. The failure of an SGT is often the cause of a major power outage affecting business and domestic consumers. The ability to deliver increased work volume in later periods will be hampered by a five-year starvation of the supply chain as well as availability of outages and operational resources.
- Resilience: Failure to comply with the minimum requirements of the Security and Quality of Supply Standard (SQSS), which ensure that a level of redundancy is provided in order to tolerate a degree of asset failure without leading to widespread system disturbances.

We consider it is a sound methodology to treat this asset class as a portfolio, identifying expected failures from the population over a period (a price control period in this instance) and refining this portfolio view as end of life approaches and condition monitoring identifies specific assets in the two to five-year timescale. Condition monitoring of transformers can identify specific transformers requiring interventions as they start to deteriorate, and this allows optimisation of interventions within an expected general volume over a period of time (such as a price control period).



We have examined information provided by National Grid and Atkins (as part of the draft determination) to determine those transformers with specific condition monitoring information that would indicate a sufficiently poor condition score to warrant interventions. We identified [redacted] SGTs, [redacted] SCTs and [redacted] Reactors at or near their end of life and at a suitable point for intervention. The increase in volume from Ofgem's draft determination volumes represent assets where condition monitoring information has been received since NGET's Business Plan submission, which all meet the trigger point for intervention, on which Ofgem, NGET and DNV GL appear to agree in principle. We have also cross-checked that the number of transformer changes per year is broadly consistent with NGET's historic performance of [redacted] SGTs per annum. We then applied this volume to unit cost information from our own database [redacted] to establish the overall associated costs.

On this basis, we consider the minimum required volume of replacements is [redacted] transformers and [redacted] reactors, at a cost of £205m.

i https://www.ofgem.gov.uk/publications-and-updates/riio-2-draft-determinations-transmission-gas-distribution-and-electricity-system-operator.
ii Ofgem, RIIO-2 Draft Determinations – Core Document, 9 July 2020, p6, available at https://www.ofgem.gov.uk/system/files/docs/2020/07/draft_determinations_-_core_document_redacted.pdf.
iii See, among others: https://news.energynetworks.org/news/response-to-proposed-settlements-for-riio-2;
https://investors.nationalgrid.com/~/media/Files/N/National-Grid-IR-V2/financial-news/2020/Ofgem%20Draft%20Determination_09July2020_FINAL.pdf;
https://www.sse.com/news-and-views/2020/07/ssen-transmission-response-to-ofgem-draft-determination-of-riio-t2-price-control/;
https://www.spenergynetworks.co.uk/news/pages/sp_energy_networks_responds_to_ofgems_proposed_settlements_for_riio_t2.aspx.
iv https://www.ofgem.gov.uk/about-us/our-priorities-and-objectives.
v Ofgem, RIIO-2 Draft Determinations – Core Document, 9 July 2020, p5, para 1.1.
vi Ofgem, RIIO-2 Draft Determinations – National Grid Electricity Transmission, 9 July 2020, section 3, Table 28.
vii As per: Ofgem, RIIO-2 Draft Determinations – National Grid Electricity Transmission, 9 July 2020, section 3, Table 28.
viii https://theiam.org/knowledge/bsi-pas-55/
ix International Infrastructure Management Manual (IIMM), IPWEA 2015.
x NGET is already incentivised on Energy Not Supplied as a high-level performance output, but relating individual asset performance to its impact on the network is currently not possible. The Network Asset Risk Metric attempts to quantify this but this is a summation of risk from its components and does not take account of redundancy in the system and operating practices
xi https://www.gov.uk/guidance/the-highway-code/annex-6-vehicle-maintenance-safety-and-security.

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