Submission by the Asset Reliability Improvement Association (ARIA) on Practical Reliability Engineering Opportunities for the National Electricity System

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About this Submission

Reliability is a key component of the National Energy Guarantee (NEG) and Asset Reliability itself is integral to the overall effective operation of the National Electricity System. In consideration of this the Asset Reliability Improvement Association considers it essential to advocate where best practice in Reliability Engineering and Asset Management technologies will support the goals of the NEG.

About the Asset Reliability Improvement Association (ARIA)

The Asset Reliability Improvement Association (ARIA) is a recognised industry peak representative body in the Australasian region for the discipline of “Condition Monitoring and Reliability Improvement” for physical assets. Its mission is to define, support and promote good practices within the Condition Monitoring and Reliability Engineering fields. ARIA maintains broad contacts with the Australian and New Zealand maintenance and engineering communities through its networks and brings together volunteers to work on projects identified by its members. Its members sit on various Australian and ISO Committees for Asset Management and Condition Monitoring and are industry leading experts in Asset Management, Reliability Engineering and Condition Monitoring and derive from a wide range of industries such as petrochemical, oil & gas, power generation, metals processing, and mining.

Electricity Systems (Background Information)

Electricity supply systems form the backbone of modern life. Most businesses depend on reliable low-cost electricity to operate. Almost all individuals and families are dependent on electricity to live their daily lives. The need for electricity will only grow in the future as it is the main energy source where there are now new technologies available to generate it without burning fossil fuels. The value of a reliable, low cost and low emissions electricity supply to Australia can't be overstated.

Without major technology breakthroughs renewable sources of electricity are likely to become the major source of energy replacing fossil fuels. As the pressure to reduce carbon emissions increases energy sectors such as transport, industrial processes and stationary energy are expected to add additional load onto the existing electricity infrastructure.

Electricity System Reliability (Background Information)

The National Electricity System is made up of innumerable mechanical and electrical components that must work together effectively to provide reliable electricity supply to the National Electricity Market's (NEM) 9 million customers. The Australian Energy Market Operator's (AEMO's) role is to match customer demand with system supply from sources of electricity generation connected through the NEM's transmissions network. Customer demand varies so there must be a surplus in supply to meet peak demand levels. There can also be variations in supply due to unexpected failures in generation or transmission systems. The risk of such failures necessitates additional surplus in generation supply and redundancy in transmission systems to avoid loss of electricity to customers.

Surplus in generation and redundancy in transmission by its very nature is very expensive to provide. The lower the level of this surplus in maintaining electricity reliability the lower the average cost to generate and deliver electricity. In turn, this must be balanced against the market forces driving prices for customers higher and increasing the risk of poor reliability when supply is restricted. Over the last few years the availability of high spot prices has proven not to have driven investment in new generation in a timely manner, largely due to technology change uncertainty, uncertain government policy, high levels of capital investment required and other barriers that limit investor entry into the market. These factors and the present comfort of many of the current stake holdings in the current market system are limiting the changes and investments that are required. NEG will have considerable difficulty in meeting future Australian energy requirements if it does not leave room for innovation and open the market for new investors.

There are significant opportunities for the AEMO to better manage the complexities involved in finding the right balance between supply, reliability and cost. Two methods of minimising costs relating to electricity supply, demand and reliability are given below.

- Variation in customer demand above available supply can be minimised by demand response management
- Reducing unexpected variations in supply caused by **asset** failures within the system by application of reliability engineering technologies and practices

Another major risk to both reliability and cost for electricity consumers is how asset repair and replacement decisions are being made. There are major risks to reliability of electricity supply due to assets not being maintained in an adequate functional condition. The ideal is to use the wide range of available inspection, testing and in-service monitoring technologies to understand the current condition of critical assets and to make repair and replacement decisions on predicted risk of in-service failures. The asset reliability levels achieved by these activities must be balanced against their cost. They also must be balanced against the asset availability reduction caused by the outages to carry out inspection, testing, repairs and replacements. For organisations that manage complex assets the biggest challenges to get this balance right are given below.

Image Source Assetivity

- Selection of an appropriate Unreliability Cost
- Application of appropriate inspection & monitoring techniques
- Management of inspection & monitoring data
- Identifying failure risk from inspection & monitoring data

There are also major risks to the cost of electricity due to excessive capital spending. Three causes of excessive capital spending are given below.

- Asset replacement where repair was viable
- Installing new assets before they are required. Delaying expenditure saves money
- Installing overly expensive assets or projects where lower cost assets or projects would have been viable.

These three misuses of capital are widely termed Gold Plating. The methodology used for proper management of these decisions is Asset Management. The international standards pertaining to this are ISO 55000, 55001 and ISO 55002. These are supported by extensive guidelines and statements of practice generated by a range of national and international societies.

Asset Management and Reliability Engineering

The electricity industry and businesses have practiced competent Asset Management and Reliability Engineering methods and approaches. There are people within Australia’s generation and transmission businesses that are highly skilled in Asset Management and Reliability Engineering, but their influence is challenged by ongoing budget pressures and an ageing work force. Current analysis from some of the New Zealand electricity networks and a range of coal fired power stations in Australia indicate that our current electricity businesses have specific local examples of reliability-related best practice operating effectively but also many examples where it is not or is in a state of decay. Implementing sustainable, leading practice Asset Management and Reliability Engineering methodologies is a long-term process of continuous improvement. The benefits include the achievement of long term lower operating costs and lower rates of unplanned loss of supply.

In the last 5 years the ISO Standards on Asset Management have been published. These were based on the successful implementation of the UK standards PAS55. Exemplar organisations such as Scottish Power realised significant benefits from adoption of the approach backed up by advanced analytics and use of technology, case studies of which have been documented. There is also an extensive library of underpinning ISO standards on reliability and condition monitoring that form an integral part of Asset Management. Lessons learned from this body of knowledge which includes pragmatic application to power companies state that it is important that all the NEM electricity network assets should be managed as an integrated system to ensure that electricity consumers are delivered the most appropriate service at the lowest cost. This can be achieved by the requirement for adoption of, and compliance to, Asset Management best practice standards. These incorporate detailed knowledge of the current and future condition of the assets, scenario modelling to test risk to the network under credible load cases, and informed business processes practiced by the power companies to reduce risks and deliver requisite performance at optimal cost

The challenge for Government is that whilst best practice for Asset Management is fully documented in ISO Standards and supporting materials published by authoritative societies, their adoption and compliance is not a requirement nor even a recommendation from Government regulators. This may be compared to the NZ context where the Commerce Commission has actively utilised the lessons of the UK PAS 55 (mentioned earlier) to at least influence improved asset management practices in the power companies of that country. The net effect of this in Australia is lower reliability, poor availability, lack of capacity and capability, high costs of ownership and network supply failure. To this end the ISO committee on Asset Management (ISO TC 251) is currently drafting guidance on Government Policy for Asset Management which is expected for draft publication next year. This guidance, however, will not substantially improve the NEM reliability and availability if such guidance is not adopted or mandated by Government.

Sharing Asset Management and Reliability Best Practice

Many Australian businesses have achieved significant improvements in their asset reliability at low cost through sharing of best practice through inter-business networking processes and expert best practice challenge processes, such as those run by the SIRF Roundtables organisation. These businesses can verify the power of these process to help improve their business outcomes. One of the most important areas of best practice is asset inspection and condition monitoring techniques to determine current asset condition and predict potential failures. Australia electricity customers would significantly benefit from all businesses within the NEM sharing their reliability best practice knowledge and systems. Setting best practice standards and ensuring there are systems and training available to broadly implement these standards has been shown to result in significant benefits by many Australian businesses. This could be facilitated by an organisation such as AEMO by employing a small group of Reliability Engineering/ Organisational Network experts to facilitate these networking processes. Australia electricity customers would significantly benefit from all businesses within the NEM having their reliability best practice challenged by a range of external reliability experts. This is called Best Practice Challenge.

Asset Condition Monitoring Systems - A key Reliability Engineering process that will deliver fast pay back is the broader implementation and increased effectiveness of Asset Condition Monitoring Systems. This involves the measurement of asset condition across the spectrum of asset classes utilised in power companies to determine the health and potential failure of specific assets. This process identifies asset condition faults that may lead to system failures so that they can be repaired before a failure occurs. There are many condition monitoring techniques that are already well established and widely used by NEM businesses. Experience has shown that without external audit and expert challenge they are often unevenly applied, not well focused on the highest risk assets and often the collected data is not used effectively. Condition monitoring techniques should be supported by advisories groups that produce implementation methodologies for the benefit of the wider industry and ultimately the consumers. Experience has shown assets such as high voltage circuit breakers being returned to service with critical measurements out of specification, with the consequential catastrophic failure. See appendix A for a range of Condition Monitoring methods that are available for electricity transmission assets.

Asset Performance Monitoring – One monitoring methodology that is important for emission reductions and output capacity is Asset Performance Monitoring. The efficiency and output of especially coal fired generators can easily be affected by a wide range of factors. Factors such as warn turbine blades are often know but there can be a range of other factors that can remain hidden without rigorous testing. Lower conversions efficiencies from coal to electricity create an unnecessary increase in emissions. It is important that conversions efficiencies are measured rather than assumed so that inefficiency emissions do not remain hidden.

High Voltage Transmission Network Reliability – The backbone of the NEM asset system is the High Voltage (HV) transmission network. The HV network would typically include 110, 220, 330, 500 kV for transmission and 110, 33, 22 kV for distribution systems. The management of the reliability of this system should be given a high priority and should be achieve without 'gold plating' the asset or adding redundancy before it is needed. Most faults on the electrical side of these assets usually grow slowly over time and hence require good asset management systems to be in place to manage the future reliability. As an example, current work is progressing on the use of SCADA for real time diagnostics of HV systems and other work is progressing Smart Meters for advanced understanding of the LV network to lower risk of interruptions or issues with power quality. Even though the electrical transmission organisations will have some form of a reliability management system in place, it is important that they have their current reliability practices challenged by a range of external reliability experts to facilitate innovation and improvement. For example, modelling of the reliability of the HV network would be made much more accurate if a detailed map of the asset failure risk severity was available for the whole network. Once there is a system wide reliability plan for the HV network, then future work can progress with analysis of the very large data sets for the LV network where experience has shown there will also be major opportunities for reliability improvement.

Asset Criticality Analysis, Bad Actors and Weak Links – Another Reliability Engineering process that would achieve fast pay back for effort required is Asset Criticality Analysis and the identification of Bad Actors and Weak Links. These processes identify the specific assets that will show the most benefits from reliability improvement effort. An example of what can be achieved with Bad Actor problems is where the Pacific Power was given responsibility for driving reliability improvement of the then government owned coal fired power stations in NSW. A boiler tube failure reduction campaign resulted in a reduction from 65/yr to around 10-12/yr resulting in production savings of around $2-3 million per failure ($100-150 million/yr). This campaign was recognised by the US-based EPRI organisation an international exemplar of leading practice. It is noted that following privatisation and cost pressures, boiler tube failure rates have accelerated in NSW power stations where teams now have less intellectual resources, experience or tools to cope with this persistent problem at a time the units are ageing into their end lives.

Another example of a Weak Link is the initial High Voltage transmission tower that failed in the 2016 South Australian electricity loss incident. An asset failure like this and the other weak links that the failure unearthed is an embarrassment for Australia. A failure like this may well be expected from a 3rd world country but Australian engineering and know how should retain this critical infrastructure in operable condition at all times. The question is how often these towers were inspected by competent structural inspectors who were supported by experienced structural engineers. Also, what was done with the data and whether appropriate funding was made in response to technical recommendations. This is an important example where competent asset management relies on detailed knowledge of the condition of the assets both now and estimated into the future. It is common with complex asset systems to have weak links that are known about but where the risk is either not understood or ignored. It is important to have good systems for the management of inspection and monitoring data to ensure this does not happen.

Management of Inspection and Monitoring Data

Success in Asset Management is mostly about the rigour and discipline in how information is collected, stored, analysed and used. The more complex and numerous the assets, the more rigour and discipline is required. For many years organisations have used Computerised Maintenance Management Systems (CMMS) to plan and schedule their maintenance activities and collect asset history and most organisation have developed good practices around their use. The collection, storage, analysis and use of asset condition information is difficult to manage using Maintenance Management Systems. Best practice is the use of a separate Asset Condition Management System (ACMS) to classify and record the failure risk severity of faults and the criticality of the asset. The key part of this process is the conversion of asset condition information to failure risk severity by predicting the likelihood of in-service failure. Where asset faults develop slowly over time an Asset Condition Management System ensures faults are not ignored or forgotten. An example of a best practice ACMS within Australian business is the OneSteel OneCare system. One key purpose of an ACMS is to be able to visualise serious faults at an asset level, at a system level, at a regional level and at the total system level. This data can be used to significantly improve estimates for the current asset systems reliability for use in the reliability modelling used to make asset investment decisions. Another use of ACMS data is to assess the quality and effectiveness of asset management processes to maintain the functional effectiveness of asset systems.

One area the power companies will benefit is to extend the example of international organisations such as CIGRE and IEC, developing open source advisories on inspection procedures, detailed measurement points for asset classes, tolerable limits for flaws and condition levels, and to provide these advisories to power companies who may otherwise struggle to find the investment to collate such information for themselves.

Capital Investments

As stated in the introductory background information there is a major risk to Australia's ability to produce low cost electricity due to excessive capital spending on electricity infrastructure assets. A key opportunity for lowering electricity costs is reducing or delaying capital asset expenditures. The better the quality of quantitative and qualitative reliability data for NEM system assets, the better the cost, risk and benefit trade-offs that can be achieved.

It is vital that major investments in electricity system assets are made from wholistic modelling of the NEM system including a wide range of future scenarios for investment options that could influence the requirement and optimum timing of investments. This should include the innovative solutions that are currently being proposed and experimented with. Investments in asset systems like new interstate connectors and the Snowy Two projects are likely to be vital for future reliable operation of our electricity system but without these investment options being compared to a range of other investment options, the timing of these investments are unlikely to be optimised. It is widely accepted that one of the causes for NEM's current high electricity costs to customers is the excessive capital investment in transmission assets. It is easy for those setting policies for NEM's investment decisions to feel that supporting large project investment decisions is likely to be the conservative low risk option for Australia. What should be kept in mind is the most vulnerable electricity customers who won't be able to pay their bills and the businesses that will shut down and possibly relocate overseas because of high energy costs.

Electricity Reliability and Demand Response Systems

The technical engineering meaning of reliability is not immediately relevant to the average electricity customer. Every customer is likely to have differing perceptions of what electricity reliability levels are acceptable. Historically, domestic customers have not been given a choice of the reliability of their electricity supply. If customers were given a choice, their reliability requirements may well vary significantly depending on the function the electricity is performing. Some basic domestic examples are given below.

- If electricity is being used to cook the meal for a major family gathering, then no failure of the electrical supply is likely to be considered acceptable at the time when it occurs. A somewhat higher price for the electricity to achieve this reliability is likely to be accepted.
- If electricity used for non-essential lighting is lost, then customers would likely find it inconvenient, but many may find it acceptable if it led to a lower electricity bill.
- If electricity is being used to circulate water in the household swimming pool, then if the electricity supply was not available 3 hours out of 24 then it would have little effect on the function being performed. Many customers would likely be happy to accept unexpected loss of electricity supply to the pump if there was a corresponding reduction in electricity cost.

With future increases in non-dispatchable electricity due to greater amounts of variable wind and solar PV generation then the average domestic customer should be engaged in decision-making to help manage the timing and levels of their use of electricity. Smart metering systems are being widely discussed as a way to collect data, so consumers and retailers can better understand and manage electricity usage. The same or similar smart metering technologies could also be used by AMEO as smart controllers to directly control or influence customer usage, if authorised by the customer. A significant percentage of electricity use is intermittent and the ability for AMEO to influence this use is highly desirable. This could, over time, dramatically increase AMEO's ability to manage demand to match short term variations in supply. ARIA has been given an example where a commercial customer was given the choice to increase their electricity supply reliability with an increased cost and unexpectedly chose lower reliability. There has been significant public discussion about the damage being caused to businesses from higher energy costs so the need to achieve this should not be taken lightly.

Smart metering systems should be implemented in a way to ensure that individuals and families who struggle most to pay their electricity bill are given simple practical ways to reduce these costs. These customers are very likely to accept less reliability with many more losses of electricity supply to reduce their bills, especially if most of these supply losses can be predicted and communicated in advance. The ethics of electricity retailers should be monitored to ensure that the most vulnerable electricity customers are being protected. We do not want to see a Royal Commission into Energy Retailers in 5 years' time.

Standards should be set for installation of Smart Metering systems in new building electrical systems or when building electrical systems are being upgraded. Some domestic circuits, such as for refrigerators, computers and key lighting requirements, should be separated as requiring high reliability. Circuits used for high load appliances such as air conditioners and clothes driers should be separated for possible emergency load shedding, or demand response management.

It goes without saying that Smart Metering systems should be implemented comprehensively through commerce and industry at a rate that will achieve a good payoff to electricity customers. They should be encouraged to do this with cost savings from a wide range of reliability and demand timing electricity supply products. Different functional uses of electricity will require a range of demand response approaches with difference reliability requirements. It is suggested at least two or three control circuits should be specified for domestic use. All levels of government should be encouraged to actively promote these reliability and demand response systems.

Implementation of these electricity reliability and demand response systems could be driven by the electricity retailers. Their performance in implementing these systems would need to be measured and managed through the NEG Reliability Requirements system with appropriate strong penalties for poor performance. It has been publicly expressed as a concern that electrical retailers may prefer to sell more electricity than work hard to reduce demand through implementing reliability and demand response management systems. If a truly efficient and effective NEM wide demand response management system is required, then opening the implementation and support system to more than just the just current retailers would have many advantages. The focus of this approach should be to give a much greater percentage of the financial value delivered from customers not using electricity during high demand periods directly to the customers. It is important that implementation of smart metering systems does not become viewed by the community and business as just a tool for energy retailers to drive their own corporate interests.

Asset Reliability within the National Electricity Market

Overview

The foundation for achieving high **Electricity Reliability** in the NEM, as discussed in Chapter 5 of the Draft Design Consultation Paper, is high **Asset Reliability** within the NEM system. Even with a large percentage of non-dispatchable renewable electricity, the short-term generation supply availability is predictable, and the customer demand is somewhat predictable. In the worst case of unexpected demand variation, higher operational cost generators such as natural gas powered aero gas turbines or hydro power may have to be started up quickly to meet demand.

Asset reliability by necessity needs to be split into two sections being generation and distribution. Network reliability pertains to distribution systems and includes both the distribution capability (including flexibility) the failure rate of Network elements. Generation reliability pertains to station overall reliability in terms of both capability and failure rate. Any consideration of reliability, that underpins system availability, can be completed using existing reliability modelling methodology to both report status and predict failure.

What is not currently predictable is the potential failure of an in-service generator or transmission assets. For a transmission asset failure, if transmission circuit redundancy is not available, or automatic switching does not occur, or adequate generation supply is not available on the adulterate circuit, then customers will lose their electrical supply. For an electricity generator asset failure, if the loss of supply is greater than the capacity of available generator inertia and battery storage, then customers will lose electrical supply for a short time. If there is not enough available stand-by fast start electricity generator capacity, then customers will lose electrical supply for a longer period. If multiple asset, or system failures occur together, then a much longer period of customer supply loss is likely to occur, as in the major South Australian electricity supply loss in 2016. In general, maintaining electricity supply due to asset failures is much harder and more expensive then to manage short- term changes in customer demand.

It is the view of the Chairman of the Asset Reliability Improvement Association that the reliability of the NEM's network of assets can be improved, providing far greater value to Australia's electricity customers than the cost of achieving this improvement. Also, the reliability of important elements within NEM's network can be quantified much more accurately than currently available allowing the AEMO to make better medium and long-term decisions in its management of the market.

The reliability of assets is often talked about in a way that gives the impression that asset reliability is a constant stable attribute. The reality is that an asset's reliability varies substantially in complex ways due to the factors listed below.

- Appropriateness of the design for its intended application
- How it is manufactured
- How it is transported and stored
- How it is installed
- Location and environment
- How it is operated
- How it is monitored
- Operational incidences that occur
- How it is serviced
- How it is repaired or replaced
- Service life

High asset reliability is achieved by developing and implementing best practice systems for managing all these factors. These best practice systems are required for all asset types that are critical to the reliability of the system (NEM in this case). The cost of developing and managing these best practice systems needs to be balanced against the Unreliability Cost to achieve the optimum outcome. As the Unreliability Cost may vary in different part of the system the best practice systems will also vary. The two technologies/methodologies that support these optimisations are Asset Management and Reliability Engineering.

Unreliability Cost for Electricity Generators

One key issue driving the optimisation of reliability is the Unreliability Cost. The real financial cost of asset failures to the current generator and transmission businesses may be quite small. Australia's electricity system assets are being managed by both commercial companies and semi -government bodies and they both have profit motives that do not always align with electricity customers' best interests. When asset failures cause massive short-term increases in what generators are paid for electricity, this causes a large averaged cost increase to electricity customers. A total loss of electricity supply will also cause massive costs to electricity customers. There is a public perception that the large electricity generators currently financially benefit from failures of their own equipment. This submission is not suggesting that the current generator organisations manipulate failure events, only that they are not subject to the full cost of these failures and so might not be putting their full management attention to the importance of asset reliability.

It is important to have agreed methods to quantify the cost of an electricity supply failure. This Unreliability Cost will vary between different asset systems depending on their ability to influence a loss of electricity supply and the likely length of that loss. Asset owners within the NEM should be required to use these agreed methods to calculate Unreliability Costs when making asset management decisions.

Submission Recommendations

- Adoption and compliance to the ISO Standards for Asset Management
- Implement the use of reliability engineering practices and processes as it is a proven method of providing long-term confidence and reliability in energy production including conventional and alternate forms of electricity.

- Ensure Reliability Engineering methodologies are used to optimise the costs of electricity production and substantially reduce the unavailability of electrical plant.
- Implement Smart Meters and similar technologies appropriate for the Australian context so that all NEM's customers can help support NEM Demand Response Management.
- Ensure Demand Response Management is implemented so that it delivers maximum value and cost savings to electricity customers
- Develop and implement a method to determine the quantitative Unreliability Cost to NEM customers for use in making Asset Management decisions for high criticality NEM assets
- Ensure all NEM assets are managed using Asset Management and Reliability Engineering best practice
- Ensure Asset Management and Reliability Engineering best practice is implemented through proven inter-organisation best practice networking processes and reliability challenge processes for all NEM asset owner and asset manager organisations
- Ensure priority is given to broad implementation of Asset Condition Monitoring best practice for NEM high criticality assets.
- Ensure priority is be given to fossil fuel power generation performance monitoring so high efficiency operation is achieved to minimises emissions
- Ensure priority should be given to implementation of reliability systems best practice for NEM's High Voltage transmission systems to achieve ongoing reliability improvements
- Implement Asset Criticality, Bad Actor and Weak Link analysis on NEM's higher criticality assets
- Implement an Asset Condition Management Systems across all NEM's asset systems to visualise and improve management of asset failure risks
- Ensure major investment policies for NEM are made using information from wholistic reliability modelling of the NEM system that includes a wide range of future scenario options with the aim of minimising and delaying capital investment to deliver acceptable reliability at lowest cost for electricity customers.

Implementation

ARIA and many of its members would be willing to participate in any Government "think tank" requiring specialists and subject matter experts in support of the goals of the NEG.

Appendix A

Networks Condition Monitoring Specification Sheet

Version 1.0
Date 14/02/2018

Code	SAP Type Specn	Description	Inspection	Inspection Description	Freq (M)
ABK	AIRBKSW	Air Break Switch	ABK1	Remote switchgear functional testing	6
			ABK2	33 kV ABS earthing test and major service	30
			ABK3	11 kV ABS earthing test and major service	60
ARR	AVRRELAY	AVR Relay			
AVR	AVR	Automatic Voltage Regulator			
BAT	BATTBANK	Battery Bank	BAT1	Battery impedance test and charger test	2
BLD	BUILDING	Grounds and Building Inspections	BLD1	Building condition assessments	1
			BLD2	Air conditioning checks	12
BUS	BUSWORK	Substation Buswork			
CAM	CROSSARM	Cross Arm (including Insulators)			
CAP	CAPACIT	Capacitor Bank	CAP1	Capacitor bank condition assessment	24
CBK	CIRBRKR	Circuit Breaker	CBK1	Indoor switchgear thermal imaging, PDA and acoustic checks	12
			CBK2	Indoor circuit breaker timing and operational test, switchgear condition and inspection of contacts	48
			CBK3	Indoor SF6 11 kV circuit breaker timing and operational test, switchgear condition and SF6 gas pressure	48
			CBK4	Indoor SF6 33 kV circuit breaker timing and operational test, switchgear condition and SF6 gas pressure	48
			CBK5	Outdoor switchgear acoustic emission, PDA and thermal imaging	12
			CBK6	Outdoor circuit breaker timing and operational test, switchgear condition and inspection of contacts	48
			CBK7	Outdoor SF6 33 kV circuit breaker timing and operational test, switchgear condition and SF6 gas pressure	48
COH	CONDUCTOH	Overhead Line	COH1	Inspection of 33 kV overhead conductors	30
			COH2	Inspection of 11 kV overhead conductors	60
			COH3	Thermal imaging of conductors (on condition)	
			COH4	Acoustic surveys of conductors (on condition)	
			COH5	LIDAR inspections (on condition)	
			COH6	Sampling of OH conductors (on condition)	
COM	COMM	Repeaters)			
CST	CARMSTL	Insulators)			
CTR	CTRANS	Current Transformer	CTR1	Acoustic emission and thermal imaging	12
			CTR2	Insulation resistance test, moisture ingress and oil change	48
CUG	CONDUCTUG	Joints)	CUG1	Record oil pressure readings	1
			CUG2	PDA on subtransmission cables	12
			CUG3	Sheath to earth resistance tests and thermal imaging of terminations of sub-transmission cables	12
			CUG4	Sheath to earth resistance tests and thermal imaging of terminations of 11 kV cables	60
			CUG5	Cable cover protection unit (SVL), cross bonding link boxes and serving tests	36
			CUG6	Earthing test	60
CWD	CARMWOOD	Cross Arm (including Insulators)			
DCB	DATACABLE	Communications Cable			
DCD	DCDISWIR	General Substation Equipment			
EAM	EXTARM	Extension Arm			
ERT	EARTH	Substation Earthing	ERT1	Substation earthing test	60
			ERT2	Substation earth mats, bonding of equipment and structure	48
FIR	FIRE	Substation Fire Protection	FIR1	Smoke detector testing	6
FNC	FENCE	Fencing and Security	FEN1	Security checks	1
			FEN2	Security system testing	6
FUS	FUSE	DDO Fuse	FUS1	DDO fuse visual inspection	60
GEN	GEN	Generator			

Code	SAP Type Specn	Description	Inspection	Inspection Description	Freq (M)
GTR	TRANGM	Ground Mounted Transformer	GTR1	Ground mounted transformer safety check	6
			GTR2	Maximum Demand Indicator (MDI) checks	12
			GTR3	Ground mounted transformer PDA	24
			GTR4	Ground mounted transformer condition assessment including oil testing (acidity, dielectric strength and moisture checks) and earth testing	60
HVF	HVFUSE	HV Fuse			
ISO	ISOLLINK	Isolating Link			
KTR	TRANKIOSK	Substation	KTR1	Distribution substation safety checks	6
			KTR2	Maximum Demand Indicator (MDI) checks	12
			KTR3	Distribution substation PDA	24
			KTR4	Distribution substation condition assessment including oil testing (acidity, dielectric strength and moisture checks) and earth testing	60
LCP	LINECAP	Line Capacitor			
LDP	LVDISPAN	LV Distribution Panel			
LFI	LNFLTIND	Line Fault Indicator			
LSP	LVSERPIL	LV Service Pillar			
LSW	LVSWPIL	LV Switching Pillar			
MET	METUNIT	Metering Unit			
OIL	OILBUND	Oil Bund			
PEE	PEE	Portable Earthing Equipment			
POC	POLECON	Pole	POLECON1	Concrete pole inspection for cracking, spalling and corrosion of reinforcing	60
POL	POLE	Pole	POL1	Wood pole testing (WEL to specify procedure)	60
POS	POLESTEEL	Pole	POS1	Steel pole inspection (coatings and rust)	60
PRO	PROTECT	Protection Breakers	PRO1	Functional check of protection breakers	12
PRR	PROTRELAY	Protection Relay	PRR1	Relay attributes check including settings and functional testing	24
			PRR2	Secondary injection tests and functional testing	48
PTR	TRANPOLE	Pole Mounted Transformer	PTR1	Pole mounted distribution transformer inspection	60
REC	RECLOSER	Recloser	REC1	Remote switchgear functional testing	6
			REC2	33 kV condition assessment, mechanism test and earthing test	30
			REC3	11 kV condition assessment, mechanism test and earthing test	60
REL	RELAY	Relays (General)			
RMU	RMU	Ring Main Unit	RMU1	Maximum Demand Indicator (MDI) checks	12
			RMU2	RMU PDA	24
			RMU3	Functional check and alarm test	96
RPR	RIPRELAY	Ripple Unit Relay			
RTU	RTU	RTU			
SBX	STCBOX	Streetlight Control Box			
SEC	SECLISER	Sectionaliser	SEC1	Remote switchgear functional testing	6
			SEC2	Earthing test	60
SFC	SFCONV	Static Frequency Convertor			
TMN	TEMPMON	Temperature Monitor			
VCR	VCRELAY	Voltage Regulating Relay			
VRG	VOLTREG	Voltage Regulator	VRG1	Thermal image survey	12
			VRG2	Ultrasonic survey	12
			VRG3	Functional check and alarm test	24
			VRG4	Earthing test	60
VTR	VTRANS	Voltage Transformer	VTR1	Acoustic emission and thermal imaging	12
			VTR2	Insulation resistance test, moisture ingress and oil change	48
WTR	POWERTRAN	Power Transformer	WTR1	Visual power transformer checks	1
			WTR2	Thermal image, PDA and acoustic survey	12
			WTR3	Transformer oil test	12
			WTR4	Tap changer service	48
			WTR5	Transformer insulation, impedance, winding capacitance, power factor tests. Bucholz and pressure relief operational test. Neutral earth resistor test	48