Efficiency Review of Maintenance Tasks

2014 - 2019 Revenue Proposal

TRANSGRID

Review of Maintenance Effort

HA01719.04 | 4

Client Reference

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Document history and status

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0	14/2/2014	Draft report	14/2/2014	R Dudley	R Dudley
1	30/4/2014	Revisions to draft report – additional detail and information	30/4/2014	R Dudley	R Dudley
2	20/5/2014	Revisions to rev 1 report to incorporate additional information	20/5/2014	R Dudley	R Dudley
3	23/5/2014	TransGrid comments and additional results included	23/5/2014	R Dudley	R Dudley
4	26/5/2014	Revisions to rev 3 report to incorporate additional information	26/5/2014	R Dudley	R Dudley

Contents

Executive Summary

TransGrid has established an operating expenditure forecast for the forthcoming regulatory control period. A significant proportion of the forecast is comprised of field based maintenance. The field based maintenance is made up of routine maintenance and inspections, corrective maintenance and major operating projects (MOPS).

To assess the efficiency of the routine maintenance and inspections component, TransGrid has engaged Jacobs SKM to review the man-hour effort for preventative maintenance and inspection tasks.

In undertaking the assessment, Jacobs SKM reviewed TransGrid's Maintenance Policies and work procedures to form a view on both the appropriateness (prudence) of the Policies and the efficiency of the man-hour effort.

Jacobs SKM found that the Maintenance Policies have been largely consistent for existing assets over the current regulatory control period, with some incremental changes to accommodate the introduction of new technologies. It would normally be expected that changes would occur in maintenance requirements between regulatory control periods as technology and associated work practices evolve. Jacobs SKM found that the incorporation of these changes to TransGrid's Policies and procedures was not likely to have an overall material impact on the forecast maintenance effort and is in line with good electricity industry practice.

Using an estimating accuracy range approach, it was found that the overall maintenance effort forecast by TransGrid is within the range of maintenance effort that Jacobs SKM has estimated. We have been able to confirm this at a macro level, with consideration of the effort required for individual tasks in forming this view.

Jacobs SKM developed a man-hour effort estimate range for maintenance tasks that made up a considerable proportion of the preventative maintenance and inspections programmes. In order to assess a representative sample, Jacobs SKM reviewed sufficient tasks in each asset type that made up approximately half of the total maintenance effort for each asset category.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs was to review and assess the efficiency of hours allocated to standard maintenance tasks in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

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1. Introduction

Jacobs SKM has been engaged by TransGrid to perform a review of preventative maintenance and inspection effort for standard tasks.

1.1 Methodology

Jacobs SKM's methodology to assess the suitability of TransGrid's effort for preventative maintenance and inspection tasks was as follows:

1. Review the forecast preventative maintenance and inspections effort for the 2014/15 – 2018/19 revenue control period, separating the tasks by asset type;
2. For each asset type, identify the combined tasks that make up 50% of the total forecast effort for the forecast period;
3. Review the Maintenance Policies for the asset types to understand the maintenance and inspection requirements / scope;
4. Develop task requirements, resource allocations and estimated effort for performing maintenance and inspection tasks identified in the Maintenance Policies;
5. Review TransGrid's maintenance procedures / task procedures to determine alignment with Jacobs SKM's assumptions in step 2.
6. Discussion with TransGrid on material differences to ensure accurate alignment and understanding of scope and output for maintenance and inspection tasks;
7. Reporting.

The maintenance effort considers the total effort (in man hours). This aligned with TransGrid's approach for forecasting man-hour effort. All associated effort required to complete maintenance tasks was estimated (for example, travel time to site was included in the effort allowed).

1.2 Review team

Jacobs SKM selected a team of highly experienced industry professionals from across Australia to perform the review. The reviewers were selected on the basis of their experience and exposure to transmission network service providers with assets of a similar or identical nature to TransGrid.

The team members and their credentials are as follows:

Roy Hart

Roy has considerable industry experience both in Australia and internationally having started as an electrical apprentice in 1964. He has a general background in Power Engineering particularly in the areas of high voltage networks and power generation. Roy has experience in the design, construction and maintenance of power generation plant, networks and associated equipment. He has been involved in the investigation of major equipment failures, technical audits, asset condition assessments and power system studies.

Roy's focus on the review was the maintenance and inspections associated with substations tasks.

Paul Blanchfield

Paul has had a distinguished career in the power industry and was selected by The Board of Electrical Engineering, Engineers Australia, as the 2011 National Electrical Engineer of the Year to recognise his high achievements in the profession over more than 25 years. Paul demonstrates very strong technical leadership across several electrical engineering practice areas and is currently a member on the Australian Cigre Panel for Sub-station Protection and Automation.

Paul's focus on the review was the maintenance and inspections associated with protection, metering and substation tasks.

Joe Juchniewicz

Joe is an electrical engineer and manager with over 35 years of experience in electrical transmission and distribution network utilities and consultancy. His experience has been in a broad range of areas from substation protection and system planning through to management supervision of network utility work forces and transmission asset management. He has been involved in the planning and construction of sub-transmission and distribution networks in the metropolitan and rural areas of SA including the assessment of large and disturbing loads. He has worked for both ETSA (1971 -1999) and ElectraNet SA (2000-2003).

Joe's focus on the review was the maintenance and inspections associated with transmission line tasks.

Kerim Mekki

Kerim is a senior executive electrical engineer with fifteen years of experience as an electrical and power consultant. He has experience in projects delivery, in business development, and in team management. He has experience in high voltage electrical installations, transmission lines and substations, high voltage power network modelling and power quality analysis, power plants, renewable energies, mining industry, hydropower, and large pumping stations.

Kerim's focus on the review was the maintenance and inspections associated with transmission lines, metering, protection and substation tasks.

Phillip Grieshaber

Phillip has demonstrated accomplishments in planning and coordinating public utility development projects over a 30 year period. He has managed development and implementation projects for power, water and gas utilities, gaining experience both while working for the utilities and for equipment suppliers of various types of real time systems and as a Senior Consultant in this field. As such he has built up an extensive knowledge of these systems, their markets and the clients they serve. He has extensive experience in substation automation systems for transmission and distribution networks.

Phillip's focus on the review was the maintenance and inspections associated with metering, communication and controls tasks.

Mike Tamp

Mike Tamp is a senior consultant in the Strategic Consulting practice area with over 30 years' experience in the NSW electrical supply industry at both transmission and distribution levels. His core areas of expertise are strategic asset management, network investment planning and risk management, asset information management and regulatory matters. Mike has 15 years direct experience in the network investment and asset management planning area at both transmission and distribution levels, with over seven years' experience in asset renewal planning and network strategy development.

Ryan Dudley

Ryan's area of specialisation is in the regulation and technical management of transmission and distribution networks. He has provided strategic advisory services to transmission and distribution network businesses and regulators across Australia, the Philippines, the Solomon Islands and Oman. He has a position on the Australian Cigré AP C5 panel (Electricity Markets and Regulation) and has recently completed projects including analysis and review of revenue proposals, asset management reviews, performance and technical audits and asset valuations. Ryan is a PAS-55 accredited assessor.

Ryan's focus on the review was the development of the methodology and assessment of the modelling outcomes.

2. Overview of TransGrid's Approach

TransGrid's approach to forecasting operating expenditure is contained in the document "*Approach to forecasting 2014/15 – 2018/19*".

TransGrid uses an operating expenditure model to forecast expenditure. The model uses a number of inputs in the calculation of operating costs in each year of the revenue control period. The Maintenance component accounts for approximately 43% of the total forecast operating costs for the next regulatory control period.

In TransGrid's forecasts, Maintenance is further divided into the following activities:

- Preventative maintenance and inspections;
- Condition based maintenance;
- Corrective maintenance; and
- Major operating projects (MOPS).

Preventative maintenance and inspections makes up approximately 35% of the Maintenance activities.

2.1 Approach to forecasting maintenance and inspections expenditure

The approach used by TransGrid to forecast preventative maintenance and inspections is as follows:

> *Maintenance inspections and routine preventative maintenance tasks are scheduled by TransGrid's enterprise resource planning system in accordance with the maintenance requirements set out in TransGrid's maintenance policies. Maintenance intervals or operations based triggers are defined based on manufacturer's advice, TransGrid's experience and good electricity industry practice….*
>
> *Forecast maintenance costs are therefore based on forecast effort for each particular year from the enterprise resource planning system (in employee hours) and hourly maintenance unit rates from the base year.*
>
> *(Source: Approach to forecasting 2014/15 – 2018/19)*

This approach is diagrammatically illustrated in Figure 1 and consists of a building block approach.

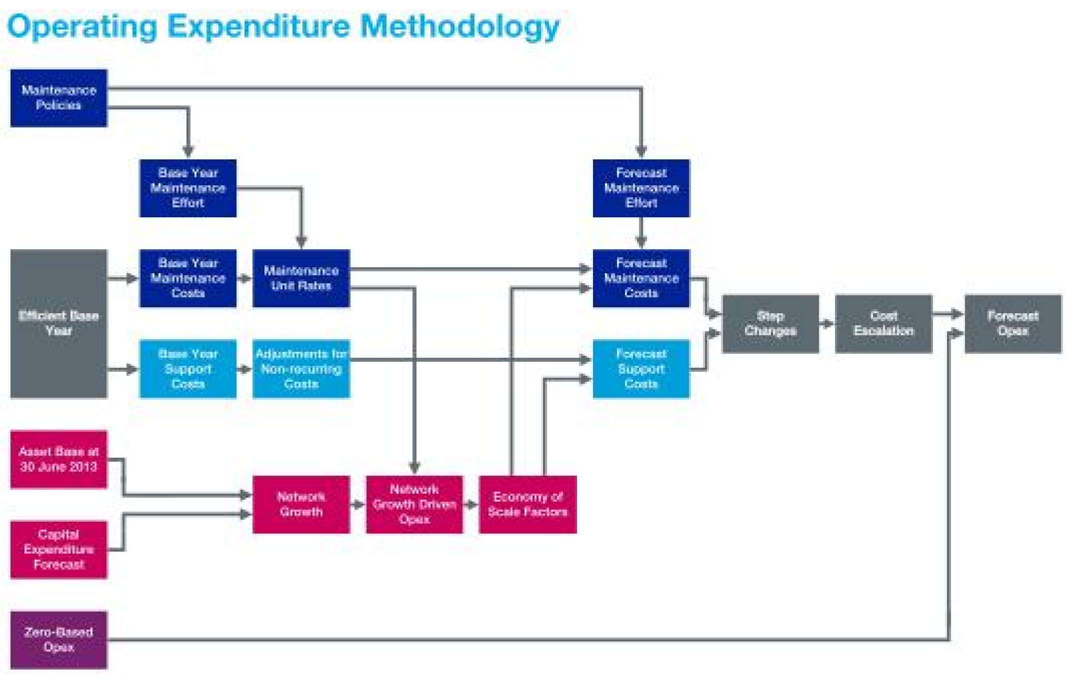

Figure 1 - Operating expenditure methodology (Source: TransGrid - Approach to forecasting 2014/15 - 2018/19 document)

The building blocks related to the forecast of maintenance and inspections expenditure are discussed in the following sections.

2.2 Maintenance Policies

As shown in Figure 1, one of the foundational building blocks for forecasting operating expenditure is the Maintenance Policies. The Maintenance Policies set the intervals and trigger points for performing maintenance activities.

2.3 Maintenance Effort

As shown in Figure 1, a critical input to the operating expenditure forecast is the Forecast Maintenance Effort. This effort is in the form of employee hours that are required to complete the maintenance tasks.

For preventative maintenance and inspections, the effort required to complete a standard maintenance task is calculated based on historical data contained in TransGrid's enterprise resource planning system. Each standard task is allocated a unique identifier. The system schedules tasks in accordance with the Maintenance Policies. When a task is completed, the resource time is booked to that identifier. In this way, it is possible to calculate the average time to complete a task by dividing the total hours booked to the task by the number of times the task has been performed. This value is then used as the Maintenance Effort for forecasting purposes.

The average time to complete a task will vary due to a number of factors, such as differences in travel time depending on location and differences in terrain and access for transmission line maintenance.

3. Discussion of TransGrid's Approach

The following discussion is based on the review of the documents contained in Appendix A.

3.1 Maintenance Policies

In preparing for the 2009/10 – 2013/14 regulatory control period, TransGrid engaged SKM to conduct a review of Maintenance Policies. The purpose of the review was to determine whether the intervals and triggers for performing maintenance activities were prudent and in line with good industry practice. The outcome of the review was as follows:

> *SKM's high level review of TransGrid's maintenance policies suggest that TransGrid conforms to what SKM considers good industry practice. The policies attempt to provide for a minimisation of maintenance whilst maintaining and achieving the corporate objectives of safety, reliability, security and availability of the network within a quality management framework.*
>
> *SKM considers that the central components of the maintenance policies present a prudent attempt to maintain TransGrid's transmission network to acceptable standards. The policies are up-to-date and incorporate maintenance activities that are practiced throughout the industry.*

(Source: Review of TransGrid's Maintenance Policies, Standard job hours and overall opex spend, April 2008)

Jacobs SKM understand that the Maintenance Policies have undergone review and improvement since the 2008 review by SKM. In general, the Policies that govern the maintenance requirements for the forthcoming control period are generally consistent with those reviewed previously.

Jacobs SKM has conducted a review of the changes and found that the introduction of new technology since 2008 has been typically associated with improved management of asset risks (e.g. online condition monitoring), external drivers (e.g. additional security systems) or improving staff and public safety, and has not materially impacted on the man-hour effort required to perform the task.

One example of this is the high-resolution digital photography of transmission lines. Under the previous Policy / Procedure, a visual inspection of the towers and lines required a helicopter to hover in close proximity while an operator performed the inspection. The new maintenance practice is to take a high-resolution photograph of the asset and perform the inspection in the office using the photograph. It is considered that this does not materially reduce the inspection time required; however, it does improve operator safety by reducing the risks associated with the task as the photographs can be taken from further away from the lines and tower.

The additional maintenance requirements contained in the Policies were generally found to consist of industry wide improvements in practices associated with the life-cycle management of assets. An example of this is the inclusion of on-line condition monitoring equipment; which in itself requires additional maintenance and inspection as part of the asset it is monitoring. The benefit of on-line condition monitoring is that it provides better information and data, which facilitates improved asset management decision making and reduces the risk of failure.

The following sections summarise the main changes to the maintenance policies since SKM's previous review. Jacobs SKM considers that the changes are in line with developments in the electricity industry and represent good electricity industry practice.

3.1.1 Easements and Access Tracks

A change in approach to be more proactive, and aim to bring easements into a scheduled maintenance regime where possible, rather than a primarily reactive maintenance regime.

3.1.2 Transmission Lines

Detailed aerial inspections have been replaced with aerial high resolution digital photographic inspections.

Routine LIDAR aerial inspections have been added.

3.1.3 Substations

Dielectric frequency response testing on transformers and current transformers known to have moisture above a certain level.

Dynamic contact resistance checks added for circuit breakers.

Added checks on capacitor voltage transformer terminal boxes.

Added oil containment inspections.

3.1.4 Control Systems

A maintenance policy has been developed for control systems to manage the increasing number of microprocessor based control systems.

3.1.5 Substation Online Condition Monitoring

A maintenance policy has been developed for substation online condition monitoring to manage the increasing number of online condition monitoring devices.

3.1.6 Network Security

A maintenance policy has been developed for new security systems that have been installed across TransGrid sites.

3.1.7 Protection

There have been no material changes to the protection maintenance policy.

3.1.8 Metering

There have been no material changes to the metering maintenance policy.

3.1.9 Communications

There have been no material changes to the communications maintenance policy.

3.2 Maintenance Effort

TransGrid's approach to forecasting future maintenance effort benefits from the law of large numbers. The law of large numbers provides stability of long-term results as the average of the results obtained from a large number of trials will trend towards a predictable value as more trials are performed.

In order for this forecasting and estimating approach to be reliable:

- A large number of tasks need to occur before the average can reliably be determined (i.e. the sample size needs to be statistically significant). There can be significant distortion in the output value (both upwards and downwards) when relying on a small sample size; and

- Tasks need to be repeatable with similar scope and output. Technological disruption (i.e. the introduction of a new technology) may significantly impact the forward estimates.

Jacobs SKM understands that TransGrid's enterprise resource planning system has accumulated data on maintenance tasks and effort for several regulatory control periods and therefore, there has been a large number of maintenance tasks performed and recorded that can be relied on for future forecasting.

In reviewing the documentation, Jacobs SKM considers that the Policies and procedures for the forecast period are substantially similar to those used by TransGrid in previous regulatory control periods and therefore, the scope and output of the maintenance tasks are consistent. From Jacobs SKM's review, the introduction of new technology has primarily focused on managing risk and is not considered to have materially affected the time taken to perform maintenance tasks (e.g. transmission line inspections noted above) and therefore, the historic performance is considered an appropriate measure for future forecasts.

While Jacobs SKM considers that TransGrid's methodology for forecasting future effort for preventative maintenance and inspections is suitable, the approach is inwardly focussed, only considering TransGrid's historic performance in determining future effort. To address this, TransGrid engaged Jacobs SKM as an external subject matter specialist to review the efficiency of the hours that were to be used in forecasting the operating expenditure for preventative maintenance and inspections.

4. Determination of tasks for review

Jacobs SKM reviewed the total forecast effort for preventative maintenance and inspections by task, in order to determine a suitable sample of tasks for review.

The preventative maintenance and inspections tasks were separated by asset type as follows:

- Communications
- Safety / security
- Metering
- Protection
- Substation
- Transmission lines and easements

Generally, around 10% of the tasks in each asset type made up 50% of the total effort for that asset type. For most asset types, the number of tasks was less than 10, with the exception being substation tasks where 49 tasks out of 836 substation tasks made up 50% of the effort.

Given the quantity of substation tasks required to make up 50% of the effort was considerably higher than the other asset categories, and the tasks themselves were largely similar with respect to scope and effort, a decision was made to reduce the number of tasks capture the top 22% of effort.

The tasks identified for review and their corresponding total effort and percentage contribution are shown in the following sections. The time period for forecast quantity and total hours is 6 years.

Using this method, almost 40% of the total preventative maintenance and inspections forecast would be reviewed. This, together with the fact that 50% of the effort within most of the asset types was reviewed, is considered a representative sample from which conclusions can be drawn on the overall efficiency of the maintenance and inspections.

4.1 Communications

ID	Description	Forecast quantity	Total hours	Hours per task
CTG101	SUBSTATION SITE ROUTINE MAINTENANCE	3374	13124.86	3.89
CTG601	RADIO SITE MAINT & BUSHFIRE HAZ REDUCT	1306	7620.51	5.835
CTG602	VHF REPEATER/LINK EQUIPMENT MAINTENANCE	665	3880.275	5.835

The above tasks comprise 56% of the total effort for this asset type.

4.2 Safety / Security

ID	Description	Forecast quantity	Total hours	Hours per task
G26001	Safety Compliance	2202	17131.56	7.78

The above tasks comprise 58% of the total effort for this asset type.

4.3 Metering

ID	Description	Forecast quantity	Total hours	Hours per task	Percent of total
M3014A	4 MONTHLY PULSE CHECKS	1601	9341.835	5.835	24%
M2008A	CT ACCURACY CHECK	274	5329.3	19.45	38%
M3012A	INDEPENDENT CHECK OF METERING	862	5029.77	5.835	51%

The above tasks comprise 51% of the total effort for this asset type.

4.4 Protection

ID	Description	Forecast quantity	Total hours	Hours per task
P0005A	CHECK/UPDATE LATEST RTIS ON SITE	557	18417.21	33.065
P0003A	PROTN MAINTENANCE OF ANCILLARY RELAYS	509	7920.04	15.56
P2013C	3 PH TX ROUT MAINT BUCHHOLZ & THERMALS	289	7307.365	25.285
P3151A	BUSBAR - ROUTINE PROTECTION MAINTENANCE	595	6943.65	11.67
P2013A	TX/AUX TX ROUTINE PROTECTION MAINTENANCE	380	6651.9	17.505
P3013A	PROTECTION IN SERVICE AUTO RECLOSE CHECK	934	5449.89	5.835

The above tasks comprise 50% of the total effort for this asset type.

4.5 Substations

ID	Description	Forecast quantity	Total hours	Hours per task
S0600B	3 PHASE AUTO TRANSFORMER MAINTENANCE.	185	12953.7	70.02
S0202A	132KV ASEA HLR CB MAJOR MAINTENANCE	34	2050.0	60.3
S0202B	132KV ASEA HLR CB MINOR MAINTENANCE	138	5099.8	37.0
S0951A	110V NICAD BATTERY MAJOR MAINTENANCE	345	9394.35	27.23
S0710A	CVT MONITOR RELAY CALIBRATION CHECK.	1608	9382.68	5.835
S0960A	41 - ROUTINE PATROLS	71	8285.7	116.7
S3019A	SUBSTATION SECURITY SYSTEM	1116	6511.86	5.835
S0961A	42 - ROUTINE PATROLS	71	6490.465	91.415
S0955A	OIL SAMPLE OF TX & RX (DGA & FURANS)	1412	5492.68	3.89
S0951C	50V NICAD BATTERY MAINTENANCE (COMMS.)	195	5309.85	27.23
S0600E	SF6 GAS AUTO TRANSFORMER MAINT - (HYM)	10	5134.8	513.48
S0275B	132KV ALSTOM S1-145F1 CB MINOR MAINT.	66	2439.0	37.0
S0275C	132KV ALSTOM S1-145F1 CB SERVICE INSPEC	53	1237.0	23.3
S0658A	REIN M TYPE - T/C DIV. MAJOR MAINT.	33	3337.6	101.1
S1MRUA	MAJOR SUBSTATION ROUTINE INSPECTION	12	140.0	11.7
S1MRUC	FIRE/ENV/SAF/SEC INSPECTION - 6 MONTHLY	12	116.7	9.7
S1MRUD	FIRE/ENV/SAF/SEC INSPECTION - MONTHLY	60	583.5	9.7
S1SYNC	FIRE/ENV/SAF/SEC INSPECTION - 6 MONTHLY	12	93.4	7.8
S1SYND	FIRE/ENV/SAF/SEC INSPECTION - MONTHLY	60	466.8	7.8

The above tasks comprise 22% of the total effort for this asset type.

4.6 Transmission lines and easements

ID	Description	Forecast quantity	Total hours	Hours per task
TEM050	EASEMENT MAINTENANCE 050 SPANS	327	27348.64	83.635
TEM100	EASEMENT MAINTENANCE 100 SPANS	172	23752.34	138.095
TCL060	Climbing Inspection 60	128	9958.4	77.8
TEM025	EASEMENT MAINTENANCE 025 SPANS	85	8500.0	100.0
TCL100	Climbing Inspection 100	52	5663.8	108.9
TGI200	Ground Inspection 200	114	9312.66	81.69
TGI250	Ground Inspection 250	91	9203.74	101.14
TEI250	EASEMENT INSPECTION 250 SPANS	63	8945.055	141.985
TGI150	Ground Inspection 150	108	7562.16	70.02
TGI400	Ground Inspection 400	51	7042.845	138.095
TGI050	Ground Inspection 50	237	5992.545	25.285
TGI025	Ground Inspection 25	339	5934.195	17.505
TGI100	Ground Inspection 100	130	5815.5	44.7

The above tasks comprise 47% of the total effort for this asset type.

5. Analysis and results

A review involving a desktop only assessment of such a wide ranging nature has an inherent level of uncertainty. Jacobs SKM has attempted to address this by determining a likely range of variability for each of the asset type tasks assessed.

5.1 Accuracy assumptions

In assessing the effort required to complete the preventative maintenance and inspection tasks, Jacobs SKM determined an accuracy range for the asset types. The accuracy range was primarily determined on the basis of the level of scope definition, the manner in which the assets are domiciled and the exogenous factors associated with each work procedure. In estimating the effort required, Jacobs SKM assumed a typical scenario where the accuracy range captures the inherent uncertainty of that scenario.

Asset type	Accuracy of effort estimate	Comments
Communications	± 10%	Variability is considered to be limited due to sheltered environment and integrity of equipment and sophistication of procedures
Safety / security	-5% + 15%	Potential variability due to environmental factors
Metering	± 10%	Variability is considered to be limited due to sheltered environment and integrity of equipment and sophistication of procedures
Protection	± 10%	Variability is considered to be limited due to sheltered environment and integrity of equipment and sophistication of procedures
Substation	-5 % +10 %	Variability in the condition of the equipment
Transmission lines and easements	-5 % + 25 %	Potential variability in terrain, restrictions on activities due to environmental considerations, condition of access tracks

5.2 Results

The results are presented from both an individual task perspective and an overall effort perspective by taking into account the quantity of tasks forecast to be performed in the forthcoming regulatory period. The forecast quantities of tasks are shown in the tables in section 4.

5.2.1 Individual results

Figure 2 shows the distribution of individual tasks when comparing TransGrid's estimates to those of Jacobs SKM. The figure captures the upper and lower range of the Jacobs SKM estimate and shows that the results are generally normally distributed.

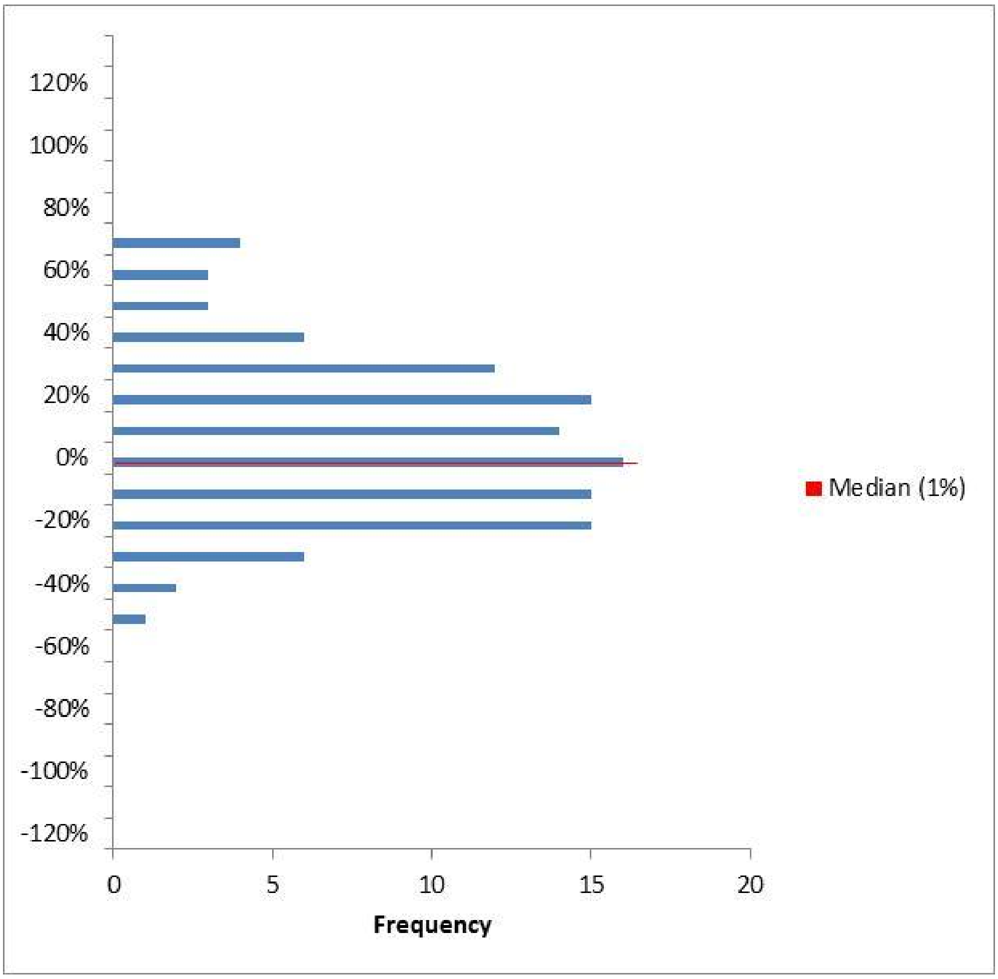

Figure 2 - Results histogram

Table 1 shows the results for individual tasks with the Jacobs SKM range.

ID	Description	TransGrid	Jacobs -	Jacobs +
CTG101	SUBSTATION SITE ROUTINE MAINTENANCE	3.9	5.0	6.1
CTG601	RADIO SITE MAINT & BUSHFIRE HAZ REDUCT	5.8	5.0	6.1
CTG602	VHF REPEATER/LINK EQUIPMENT MAINTENANCE	5.8	4.5	5.5
CXX101	SUBSTATION SITE ROUTINE MAINTENANCE	3.9	5.0	6.1
G26001	Safety Compliance	7.8	7.6	9.2
M2002A	REVENUE METER CALIBRATION CHECKS	5.8	4.5	5.5
M2006A	VT ACCURACY CHECK	23.3	14.4	17.6
M2006B	VT BURDEN & VOLTAGE DROP CHECKS	5.8	7.2	8.8
M2008A	CT ACCURACY CHECK	19.4	15.8	19.4
M2008B	CT BURDEN MEASUREMENT	3.9	3.6	4.4
M3012A	INDEPENDENT CHECK OF METERING	5.8	5.0	6.1
M3014A	4 MONTHLY PULSE CHECKS	5.8	3.6	4.4
P0003A	PROTN MAINTENANCE OF ANCILLARY RELAYS	15.6	12.6	15.4
P2013C	3 PH TX ROUT MAINT BUCHHOLZ & THERMALS	25.3	23.4	28.6
P3151A	BUSBAR - ROUTINE PROTECTION MAINTENANCE	11.7	7.7	9.4
P2013A	TX/AUX TX ROUTINE PROTECTION MAINTENANCE	17.5	15.4	18.8
P3013A	PROTECTION IN SERVICE AUTO RECLOSE CHECK	5.8	4.1	5.0
P3106A	TYPE THR RELAY ROUTINE PROTECTION MAINT	15.6	18.0	22.0
P3106B	TYPE THR RELAY PERFORMANCE CHECKS	11.7	9.0	11.0
P3119A	OHMEGA OH* RELAY ROUTINE PROTN MAINT	15.6	18.0	22.0
P3012A	CAPACITOR ROUTINE PROTECTION MAINTENANCE	9.7	5.9	7.2
P3109A	TYPE YTG RELAY ROUTINE PROTECTION MAINT	15.6	17.1	20.9
P3109B	TYPE YTG RELAY PERFORMANCE CHECKS	11.7	7.7	9.4
P3151B	BUSBAR PROTECTION - PERFORMANCE CHECKS	5.8	7.7	9.4
P3407A	GEC TYPE MBCI RELAY ROUTINE PROTN MAINT	9.7	12.6	15.4
TEM050	EASEMENT MAINTENANCE 050 SPANS	83.6	71.3	93.8
TEM100	EASEMENT MAINTENANCE 100 SPANS	138.1	142.5	187.5
TCL060	Climbing Inspection 60	77.8	69.4	91.3
TEM025	EASEMENT MAINTENANCE 025 SPANS	100.0	71.3	93.8
TCL100	Climbing Inspection 100	108.9	115.6	152.1
TGI200	Ground Inspection 200	81.7	63.3	83.3
TGI250	Ground Inspection 250	101.1	79.2	104.2
TEI250	EASEMENT INSPECTION 250 SPANS	142.0	89.1	117.2
TGI150	Ground Inspection 150	70.0	71.3	93.8
TGI400	Ground Inspection 400	138.1	190.0	250.0
TGI050	Ground Inspection 50	25.3	24.7	32.5
TGI025	Ground Inspection 25	17.5	13.8	18.1
TGI100	Ground Inspection 100	44.7	47.5	62.5
S0600B	3 PHASE AUTO TRANSFORMER MAINTENANCE.	70.0	68.4	79.2
S0202A	132KV ASEA HLR CB MAJOR MAINTENANCE	60.3	54.6	63.3
S0202B	132KV ASEA HLR CB MINOR MAINTENANCE	37.0	28.5	33.0
S0951A	110V NICAD BATTERY MAJOR MAINTENANCE	27.2	30.4	35.2
S0710A	CVT MONITOR RELAY CALIBRATION CHECK.	5.8	5.2	6.1
S0960A	41 - ROUTINE PATROLS	116.7	114.0	132.0
S3019A	SUBSTATION SECURITY SYSTEM	5.8	5.2	6.1
S0961A	42 - ROUTINE PATROLS	91.4	114.0	132.0
S0955A	OIL SAMPLE OF TX & RX (DGA & FURANS)	3.9	2.9	3.3
S0951C	50V NICAD BATTERY MAINTENANCE (COMMS.)	27.2	30.4	35.2
S0600E	SF6 GAS AUTO TRANSFORMER MAINT - (HYM)	513.5	376.2	435.6
S0275B	132KV ALSTOM S1-145F1 CB MINOR MAINT.	37.0	26.6	30.8
S0275C	132KV ALSTOM S1-145F1 CB SERVICE INSPEC	23.3	20.0	23.1
S0658A	REIN M TYPE - T/C DIV. MAJOR MAINT.	101.1	99.8	115.5
S1MRUA	MAJOR SUBSTATION ROUTINE INSPECTION	11.7	12.6	14.6
S1MRUC	FIRE/ENV/SAF/SEC INSPECTION - 6 MONTHLY	9.7	8.8	10.2

Table 1 - Results for individual tasks

5.2.2 Overall results

While the individual task effort estimates show some variation between TransGrid and Jacobs SKM, the assessment of the total maintenance effort, that is, the build-up of individual task effort multiplied by the number of times each tasks is forecast to be performed, provides an indication of the efficiency of the overall preventative maintenance and inspections forecast.

The result of multiplying the tasks quantities shown in the tables in section 4 by the man-effort hours for individual tasks in Table 1 is shown in Table 2.

Table 2 - Efficiency assessment of preventative maintenance and inspections

Jacobs SKM lower estimate	Jacobs SKM average	TransGrid	Jacobs SKM upper estimate
314,518	352,530	342,682	390,542

TransGrid’s forecast effort is within the lower and upper range of total effort estimated by Jacobs SKM and is less than the average of the lower and upper estimates. TransGrid’s forecast is therefore considered to be reasonable and efficient.

6. Conclusion

Jacobs SKM has undertaken a desktop review of TransGrid's effort for preventative maintenance and inspection tasks including maintenance of substations, protection, metering, communications and transmission lines. Jacobs SKM's estimation of the effort was based on the maintenance procedures provided by TransGrid and the industry experience of the reviewers.

TransGrid's forecast of the total preventative maintenance and inspections effort is within the range of expected effort estimated by Jacobs SKM. While there were some variations in the estimates of effort at the individual task level, variations were generally evenly spread compared to TransGrid's allocations and when taken in context of the overall maintenance effort, they appear reasonable.

Appendix A. Documents reviewed

Document Number	Document Type	Document Title	Revision Number
GM AS D1 001	Policy	Control Systems Maintenance Policy	Rev 1
GM AS L1 002	Policy	Easements and Access Track Maintenance Policy	Rev 6
GM AS M1 001	Policy	Metering Maintenance Policy	Rev 9
GM AS S1 011	Policy	Network Security Inspection and Maintenance Policy	Rev 1
GM AS P1 001	Policy	Protection Maintenance Policy	Rev 8
GM AS S1 001	Policy	Substation Maintenance Policy	Rev 14
GM AS S2 016	Policy	Substation Online Condition Monitoring Maintenance Policy	Rev 1
GM AS C1 001	Policy	Telecommunications Maintenance Policy	Rev 5
GM AS L1 001	Policy	Transmission Line Maintenance Policy	Rev 9
GM AS S1 005	Policy	Underground Cable Assets Maintenance Policy	Rev 5
GM AS S3 015	Procedure	ASEA 132kV Circuit breaker Type HLR 145	Rev 5
	Procedure	Fire Protection Manual Operations & Maintenance	
GM AS P2 003	Procedure	General Procedure for Maintenance of Protection Equipment	Rev 3
GM AS C3 100	Procedure	Maintenance Instruction for Communication Sites	Rev 2
GM AS C4 202	Procedure	Maintenance Instruction for PLC Coupling	Rev 5
GM AS M2 008	Procedure	Measurement of Current Transformer Error	Rev 1
GM AS M2 006	Procedure	Measurement Of Voltage Transformer Error	Rev 3
GM AS M3 014	Procedure	Meter Pulse Checks	Rev 3
GM AS S3 032	Procedure	Nickle cadmium alkaline battery maintenance	Rev 5
GM AS P3 119	Procedure	Ohmega OH305 Distance Protection Commissioning and Maintenance Instruction	Rev 1
GM AS S3 034	Procedure	Oil sampling instruction	Rev 6
GM AS P2 004	Procedure	Procedure for the Performance of the Busbar and Interzone Protection Maintenance	Rev 4
GM AS P2 010	Procedure	Production and Distribution of Protection Relay Test Instructions	Rev 4
GM AS M4 012	Procedure	Revenue metering installation independent check	Rev 0
GM AS P3 106	Procedure	Reyrolle THR Distance Protection Commissioning and Maintenance Instruction	Rev 1
GM AS P2 013	Procedure	Procedures for the Routine Maintenance of Transformer Protection	Rev 1
GM AS C4 101	Procedure	Test Report for Communication Substation Site Maintenance	Rev 3
GM AS C4 602	Procedure	Test Report for VHF Repeater/Link Equipment Maintenance	Rev 5
GM AS S3 029	Procedure	Power Transformer Maintenance	Rev 1
GD HS G2 050	Procedure	Safe Working Practices, Equipment and Tools – Attachment 1 & 2	Rev 4