

T R A N S P O W E R

**Transmission 2040
(Grid Development Strategy)**

Work Package 3 – Grid Asset Reliability

Consultation Material

November 2008

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Executive Summary

This document has been prepared for use in consultation workshops to be held in November 2008. The consultation workshops are intended to elicit from customers their view on expected future reliability of supply that Transpower should use for planning the system for the T2040 project. Accordingly, Transpower has not proposed targets for future performance in this document.

The document provides detailed information about historic point of supply interruption performance, and the forced and planned outages of transformer branches and transmission circuits. This information is intended to be used as a point of reference for discussing future expectations for system and asset performance.

Questions to prompt reflection and discussion are included at the beginning of each main section of the document.

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1 Purpose

This document has been prepared for use in consultation workshops in November 2008. The consultation workshops are intended to elicit from customers their view on the expected future reliability of supply that Transpower should use for planning the system for the T2040 project. Accordingly, Transpower has not proposed targets for future performance in this document.

2 Introduction

Reliability is affected by planned & unplanned outages of grid equipment.

The overall reliability of the network is determined by its design, and by the availability and performance of the components of the network. Major components of the network are transmission circuits and transformer branches.

The components of the interconnected grid are likely to affect a larger amount of load and have more widespread effects, compared to components of radial assets, which connect a limited number of supply points (e.g. radial lines, supply transformers).

This document consists of three main sections:

- historical point of service performance
- historical performance of transformer branches
- historical performance of transmission circuits

3 Source Data

Information has been extracted from Transpower databases for points of service, transformer branches and transmission circuits.

For points of service, high level information from the Quality Performance Report has been presented for:

- interruptions to off-take and to injection customers;
- for the 5 years July 2003 to June 2008;
- for forced outages only; and
- based on numbers of outages and durations or unserved energy percentage as appropriate.

For transformer branches and transmission circuits, information has been extracted for branches;

- operating at 220 kV, 110 kV and 66 kV primary voltages;
- for the 10 years July 1998 to June 2008;
- including both forced and planned outages; and
- based on both numbers and durations of these outages.

The data above has been normalised based on the populations at 30 June each year to provide average, long term, outage rate information as:

- for transformers – the performance per 100 transformers;
 - all outages of transformers for any reason;
 - outages for transformer faults or work on transformers;

- for circuits – the performance per 100 circuit kilometres;
 - all outages of transmission circuits for any reason;
 - outages for transmission circuits faults or work on transformers.

The figures in sections 5 and 6 set out the average numbers and durations of forced outages as described above. As well as the average for the 10 years, the minimum value and the maximum value during the 10 year period have also been provided in some cases to indicate the variability of the historical performance. Some high level information has also been provided on the source of the forced outage.

Forced outage information has been broken down and displayed in 5 main categories:

- environmental;
- equipment fail;
- human element;
- miscellaneous; and
- unknown.

Planned outages include outages for maintenance, upgrades and new build, repairs and other miscellaneous reasons.

4 Historical Point of Service Performance

4.1 Questions about measures of Interruption to Service performance

Q.1 The measures in this section are outputs (describing actual interruptions of service). Subsequent sections of the document provide information on some of the inputs that increase risk exposure, or may lead to interruptions to service.

Do these outputs measures and the analyses presented here provide meaningful information to customers?

Are there alternative input or output measures that would be more useful?

Q.2 Restoration times following an interruption to service will be affected by the nature of the event, but also by number and location of spare equipment and options available to re-configure the grid.

What typical restoration times do customers expect for events which have resulted in a loss of service?

Q.3 In a transmission grid such as Transpower’s, events resulting in interruptions to service are relatively rare. From time to time, there will be some very rare events which however have extremely high impact, as well as on occasion Force Majeure events.

How do customers expect such low frequency, high impact events to be managed / responded to?

Q.4 What are customer expectations for continuity and restoration following extreme events? For example for a local seismic or wind event or a flood with return periods in the table below what level of resilience would customers expect?

Return Period	Continuity maintained?	Restoration – Extent?	Restoration – Time?
100 years			
300 years			
1000 years			
2500 years			

4.2 Summary of Point of Service performance

Transpower's Quality Performance Report is published annually on the Transpower website and provides summary information on interruptions to supply in a number of formats as well as detailed site by site listings of both supply and generator point of service performance. This is the primary reference for this discussion.

High level information from the Quality Performance Report has been presented for:

- interruptions to off-take and to injection customers;
- for the 5 years July 2003 to June 2008;
- for forced outages only; and
- based on numbers of outages and durations or unserved energy percentage as appropriate.

Overall, the last 3 years show an increase in the system minutes of interruptions – even when significant (greater than 1 system minute) events are excluded. Total numbers of planned interruptions (per point of service) has also shown an increase. Generator point of service performance is stable.

While the Quality Performance Report is the primary reference for this discussion, a small number of supplementary graphs have been included here.

4.3 Off-Take (Supply) Point of Supply Performance

Figure 4-1, Figure 4-2 and Figure 4-3 show the distributions of numbers and resultant unserved energy for unplanned interruptions to supply at individual points of supply (POS). These include both partial and full interruptions to supply due to faults or human interference.

Note: The unserved energy has been calculated as the percentage of the total energy that would have been supplied from the point of supply had there not been any supply interruptions and then multiplied by 100 before being displayed. Each supply voltage and each customer at a station have been counted separately.

Figure 4-1 looks at each year for the 5 years to June 2008 and counts up the number of unplanned interruptions at individual points of supply. These figures have then been averaged over the 5 year period.

In any given year, it is expected that 70% of individual points of supply will experience zero unplanned interruptions. Overall, about 30% of individual points of supply in any given year will have one or more unplanned interruptions. While the majority of points of supply will experience at most 2 unplanned interruptions in any year, a small number may experience a significant number of unplanned interruptions in that period.

Figure 4-1: No. of Individual Points of Supply with Unplanned interruptions in any year – based on 5 year average

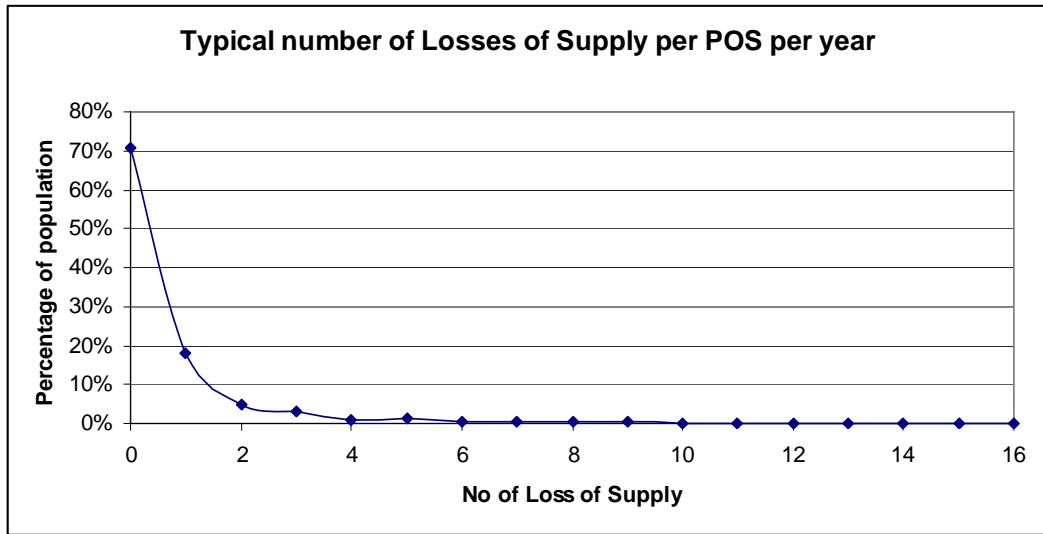


Figure 4-2 shows the average number of unplanned interruptions to supply at any given individual point of supply over the 5 year period to June 2008. (Points of supply with less than 5 years history in the selected 5 year period have been excluded from these figures).

Over the 5 year period, around 30% of points of supply (52 out of a total of 170) have experienced no unplanned interruptions to supply at all. Around 86% have experienced 1 or less, and almost 94% have experienced 2 or less, unplanned interruptions per year in that period.

Figure 4-2: Point of Supply Unplanned Interruption Rate – 5 Year Average Unplanned Interruptions per year

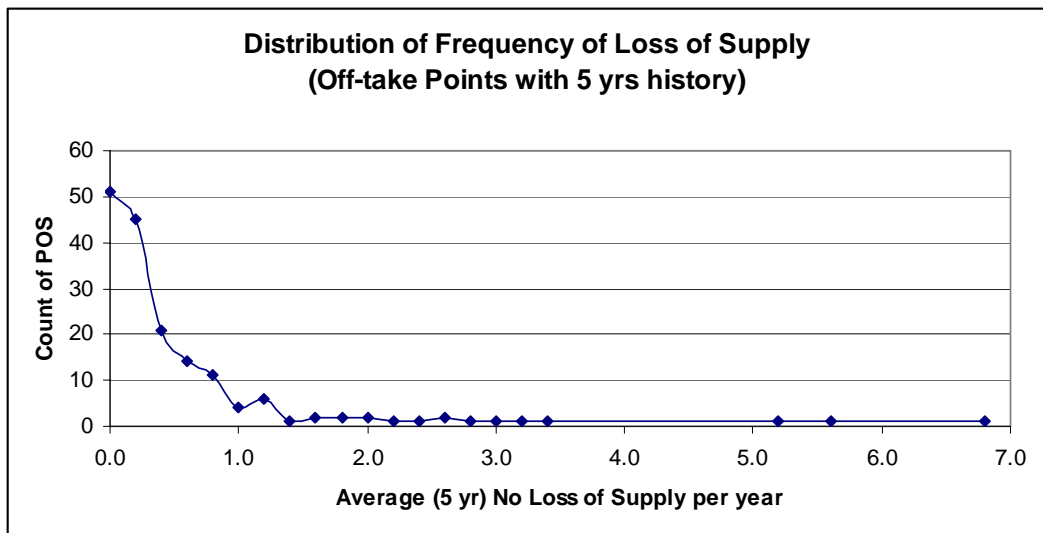
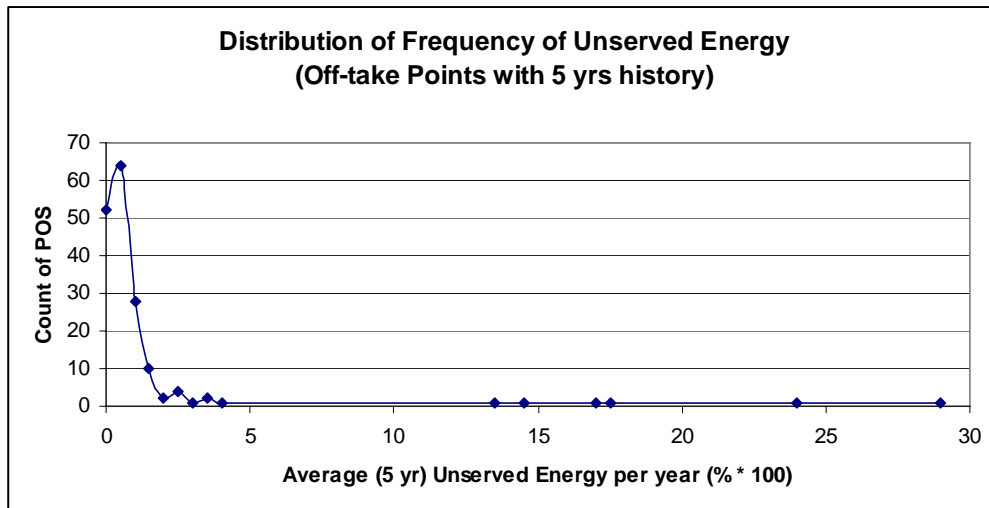


Figure 4-3 shows the average percentage (*100) unserved energy at any given individual point of supply over the 5 year period to June 2008. (Points of supply with less than 5 years history in the selected 5 year period have been excluded from these figures).

Over 91% have experienced 0.02% (displayed as 2%) or less unplanned unserved energy per year in that period. (This corresponds to 99.98% of required energy being supplied.)

Figure 4-3: Point of Supply Unplanned Unserved Energy – 5 Year Average Unplanned Unserved Energy % *100 per year



4.4 Injection (Generator) Point of Connection Performance

Figure 4-4, Figure 4-5 and Figure 4-6 show the distributions of numbers and resultant durations of unplanned interruptions to connection at individual points of connection (POC). These include both partial and full interruptions to connection due to faults or human interference. Each connection voltage and each customer at a station have been counted separately.

Figure 4-4 looks at each year for the 5 year period to June 2008 and counts up the number of unplanned interruptions to connection at individual points of connection. These figures have then been averaged over the 5 year period.

In any given year, it is expected that about 64% of individual points of connection will experience zero unplanned interruptions.

Overall, in any given year about 36% of individual points of connection will have one or more unplanned interruptions to connection. The majority will experience at most 2 unplanned interruptions in any year (almost 92% have 0, 1 or 2), but a small number may experience a significant number of unplanned interruptions to connection in that period.

Figure 4-4: No. of Individual Points of Connection with Unplanned Loss of Connection in any year – based on 5 year average

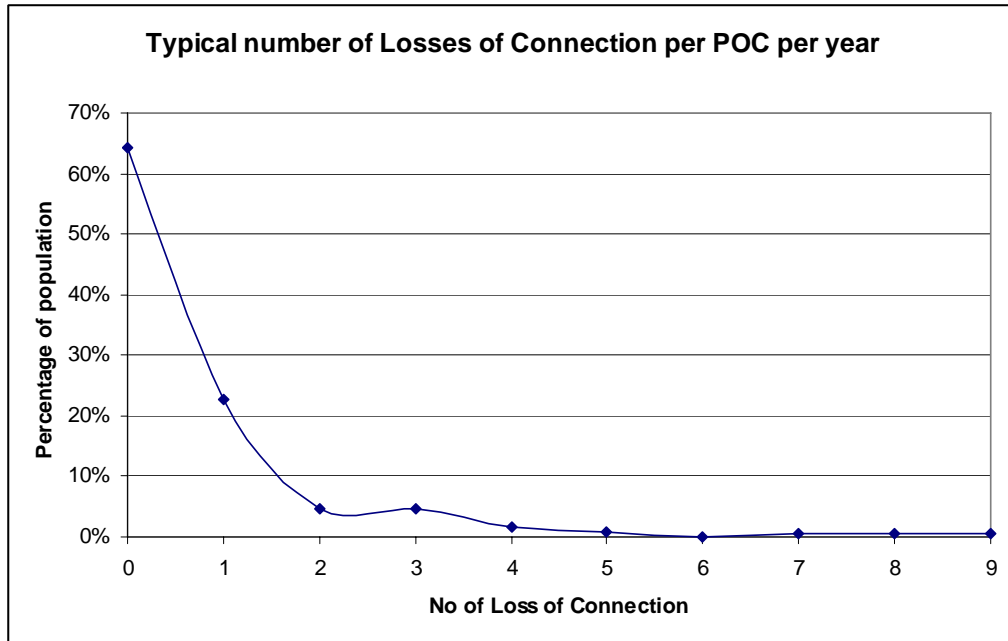


Figure 4-5 shows the average number of unplanned interruptions to connection at any given individual point of connection over the 5 year period to June 2008. (Points of connection with less than 5 years history in the selected 5 year period have been excluded from these figures).

Over the 5 year period a reasonably high number of point of connection (14 out of a total of 47) have experienced no unplanned interruptions to connection at all. Almost 83% have experienced 1 or less, and just over 91% have experienced 2 or less, unplanned interruptions to connection per year in that period.

Figure 4-5: Unplanned Interruption to Connections – 5 Year Average Rate per POC per year

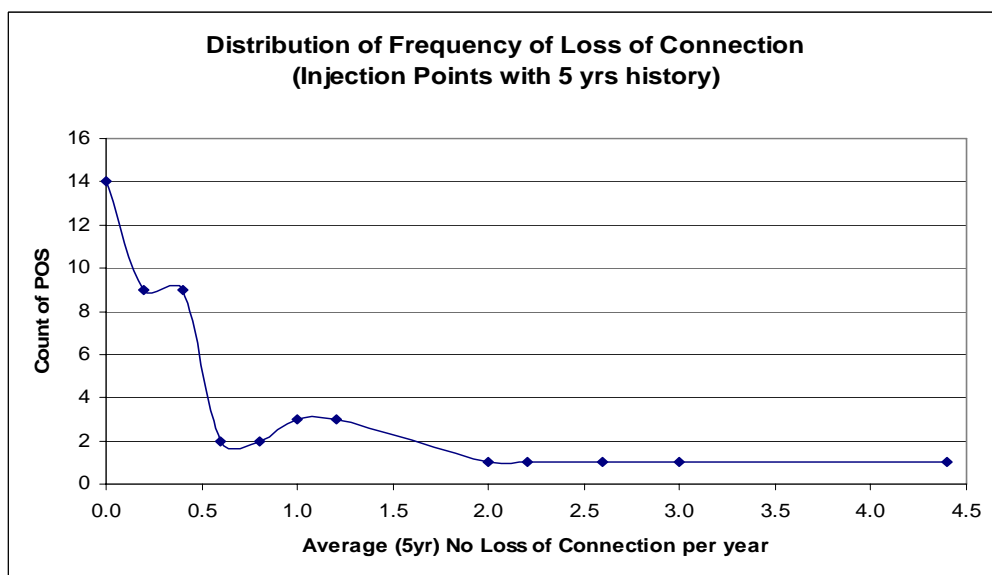
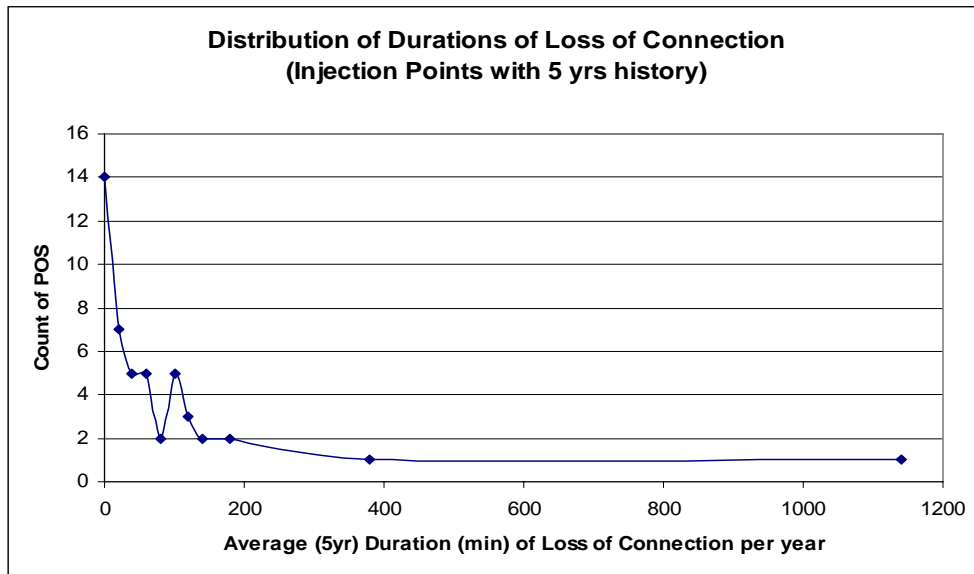


Figure 4-6 shows the average duration in minutes of unplanned losses of connection at any given individual point of connection over the 5 year period to June 2008. (Points of connection with less than 5 years history in this 5 year period have been excluded from these figures).

About 66% of unplanned losses of connection have durations of 1 hour or less, while about 87% have durations of 2 hours or less.

Figure 4-6: Unplanned Interruption Durations (minutes) – 5 Year Average per POC per year



The following sections provide information about performance of network branches:

- Transformer branches
- Transmission circuit branches

5 Historical Transformer Performance – 220 kV, 110 kV and 66 kV

This section provides an overview of the forced and planned outages and unavailability of transformer branches.

5.1 Questions and discussion of transformer branch performance

Q.1 Do the measures and analyses provided here provide meaningful information to customers?

Q.2 In this particular study, supply and interconnecting transformer performance has been combined in the analyses.

Is the same performance criteria applicable to both supply and interconnection transformers or should their performance be assessed separately?

Q.3 The majority of supply transformers at Transpower sites are configured to provide N-1 security. Therefore, generally the outage of a single transformer does not result in an obvious impact on customers, such as an interruption to, or restriction of, service. However for the duration of any outage the security will reduce to N.

Is the provision of N-1 security, reducing to N security during outages, of transformers adequate going forward?

Q.4 Restoration times following a forced outage will be affected by the nature of the event, but also by number and location of spare equipment and options available to re-configure the grid.

What typical restoration times do customers expect following a transformer forced outage which reduces security?

5.2 Summary of transformer branch outage performance

For transformer branches, equipment failure is the leading cause of both frequency and duration of forced outages. Less than 25% of these equipment failures originate on the transformer itself. International benchmarking comparisons indicate that Transpower’s average age of transformers is at the high end of those we benchmarked against. While age is not in itself an indicator of performance, nevertheless it may be expected that more equipment related issues will arise as the transformer fleet continues to age.

Planned outages are the main causes of equipment unavailability performance in terms of both numbers and durations of outages. However, as these are pre-arranged, the impact on performance as seen by end consumers is generally minimal (other than for “n” security supplies). Nevertheless, these planned outages increase risk exposure, and may contribute towards interruption events.

5.3 Frequency of Transformer and Transformer Branch Forced Outages

Figure 5-1, Figure 5-2 and Figure 5-3 show the numbers of forced outages of transformer branches per 100 transformers per annum for faults in transformer branches or on other equipment which result in a transformer being removed from service.

The information below is based on 10 years historical data and includes performance of both interconnection and supply transformers. A transformer branch includes the switchgear, protection and other plant items associated with the transformer.

Figure 5-1 is based on all transformer branch forced outages for any reason. Equipment Failure and Environmental causes are the two most common reasons for a transformer being forced out of service. This may be the result of protection operation or a manually initiated operation undertaken within 24 hours of the need for an outage being identified. The Environmental category includes weather related events as well as for example animals, birds, vermin and corrosion.

Figure 5-1: Transformer Branch Forced Outage Rate – 10 year Average, All Outages for Any Reason

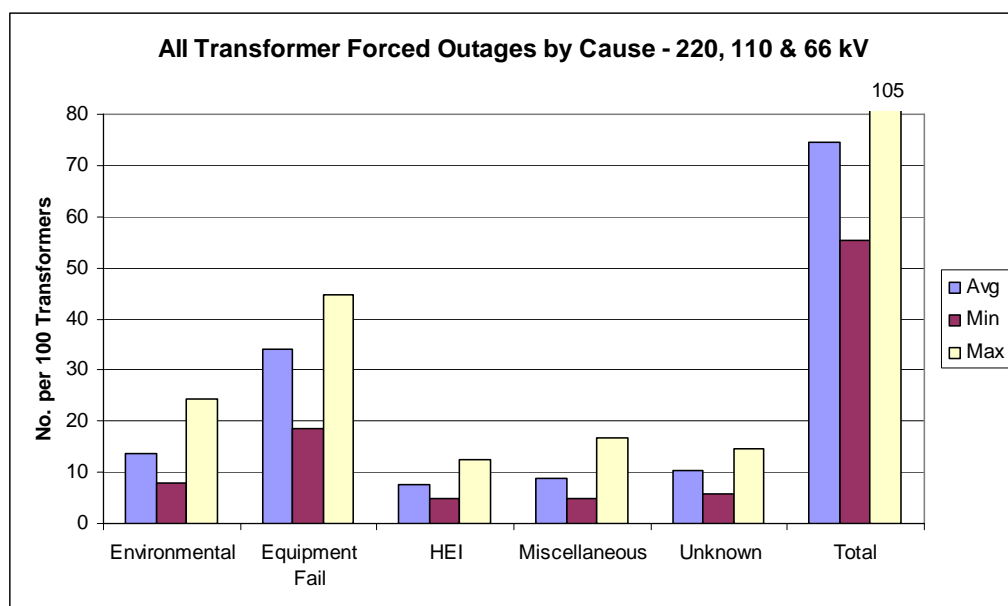


Figure 5-2 is based on transformer forced outages which were caused by events where the transformer itself was identified as the source of the outage. As might be expected, Equipment Failure is the leading cause of these outages. Again, these may be the result of protection operations or a manually initiated operation undertaken within 24 hours of the need for an outage being identified.

Figure 5-2: Transformer Forced Outage Rate – 10 year Average Transformer initiated Outage

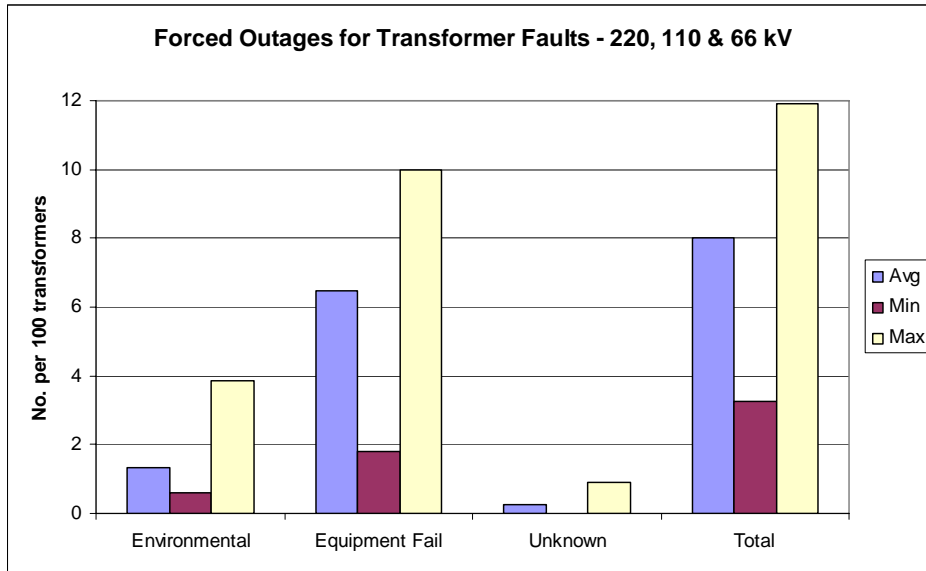


Figure 5-3 is based on the same data as Figure 5-1. However, it shows the percentage of outages in each cause category broken down by the item or source of the forced outage. Transmission line events cause most of the Environmental and Unknown events that remove transformers from service. Transformers themselves account for only a small proportion of the Equipment Failure events that result in a transformer being forced out of service. The “Other” category includes human errors, unusual system conditions/configurations, and events in customer (generator or distribution) systems that have resulted in a Transpower transformer being forced out of service.

Figure 5-3: All Transformer Branch Forced Outages – 10 year Average, By Source of Outage

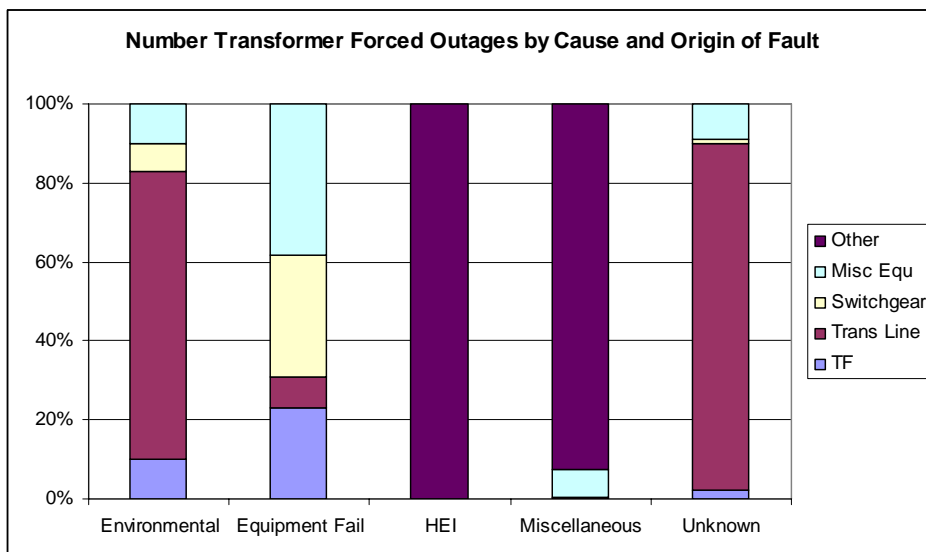


Figure 5-5 give two different views of the distribution of frequency of transformer branch forced outages. Both views are based on all transformer forced outages for any reason.

Figure 5-4 looks at each year for the 10 year period and counts up the number of forced outages on individual transformers. These figures have then been averaged over the 10 year period.

In any given year, it is expected that 60% of transformers will experience zero forced outages. Overall, about 40% of transformers in service in any given year will have one or more forced outages. The majority of transformers will experience at most 2 forced outages in any year, but a small number may experience a significant number of forced outages in that period.

Figure 5-4: No. of Transformer branches with Forced Outages in any year – 10 year Average, All Outages for Any Reason

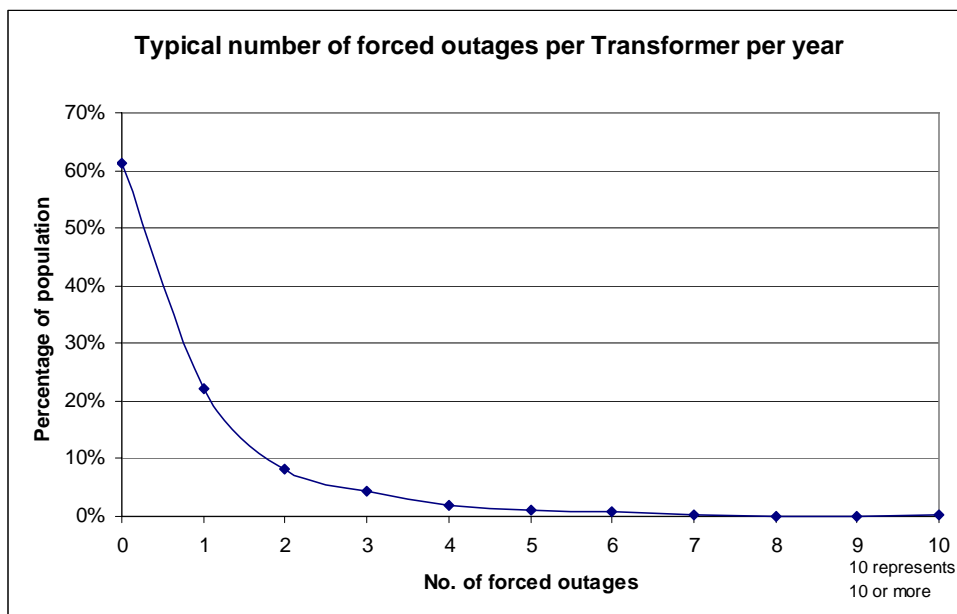
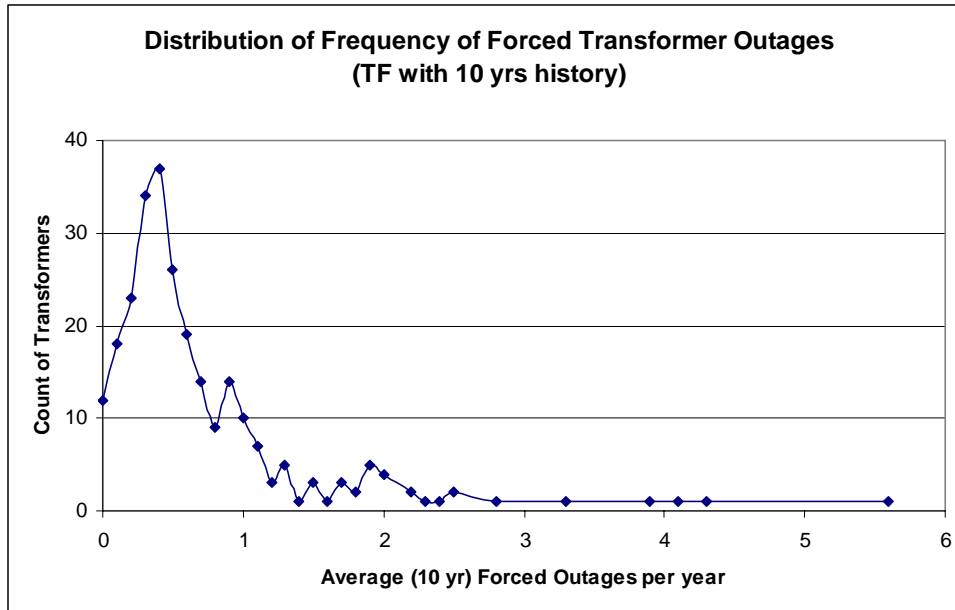


Figure 5-5 shows the average number of forced outages on any given transformer over the 10 year period. (Transformers with less than 9 years history in the selected 10 year period have been excluded from these figures).

Over the 10 year period a small number of transformers have experienced no forced outages at all in that time. The majority have experienced less than 2 forced outages per year in that period.

Figure 5-5: Transformer Branch Forced Outage Rate – 10 year Average Forced Outages per year



5.4 Forced Unavailability of Transformers and Transformer Branches

Figure 5-8 show the durations of transformer forced outages per 100 transformers for faults in transformer branches or on other equipment which result in a transformer being removed from service. A transformer branch includes the switchgear, protection and other plant items associated with the transformer.

Figure 5-6 shows the duration in hours of the outages displayed in Figure 5-1, i.e. all transformer forced outages for any reason. Outages caused by Equipment Failure have by far the most impact on the durations of transformer outages. These figures are based on individual banks of transformers. Therefore these outages in most cases do not result in losses of service to customers, although they usually result in reduced redundancy at a site and therefore a greater risk of a loss of service for the duration of the outage.

Figure 5-6: 10 year Average Durations of Transformer Forced Outages for Any Reason

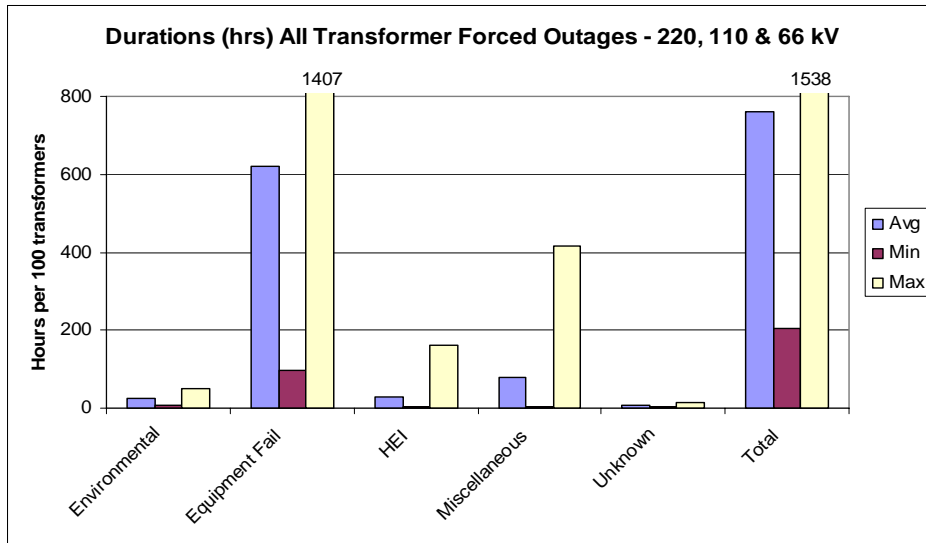


Figure 5-7 shows the duration in hours of the outages displayed in Figure 5-2, i.e. transformer forced outages which were caused by events where the transformer itself was identified as the source of the outage. Outages caused by Equipment Failure – which may require a lengthy outage for repair - are essentially the driver for this performance.

Figure 5-7: 10 year Average Duration of Outages where Transformer initiated Outage

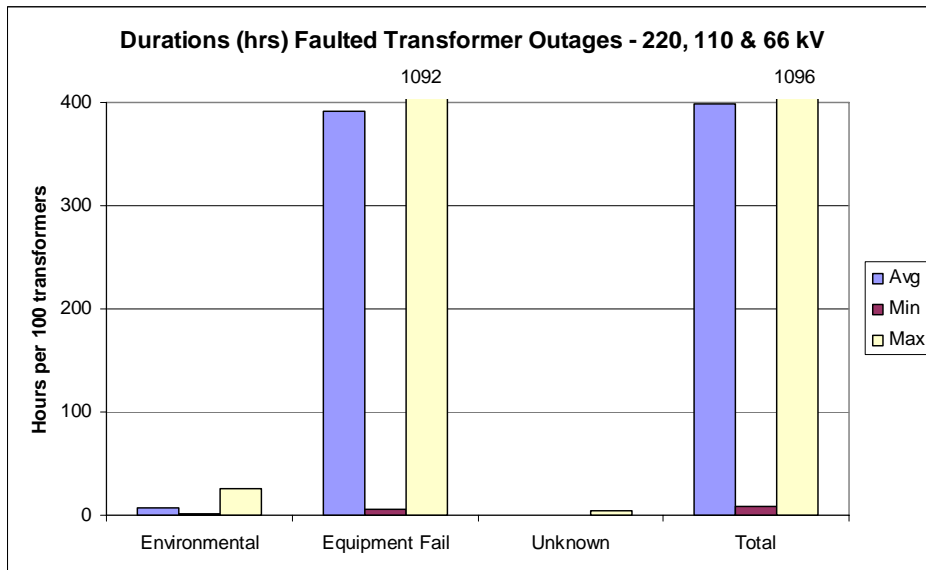
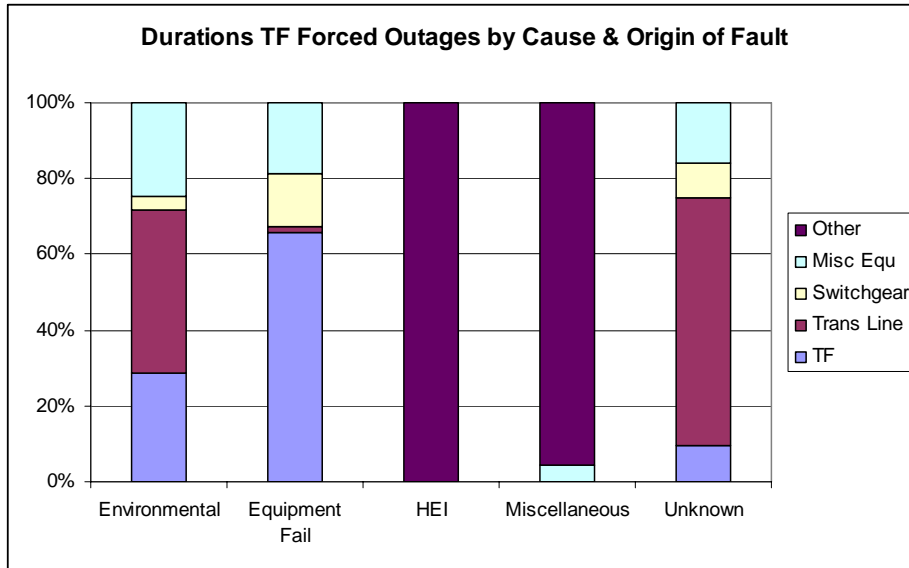


Figure 5-8 shows the duration in hours of the outages displayed in Figure 5-3, i.e. all transformer branch forced outages for any reason. However, it shows the percentage of outages in each cause category broken down by the item or source of the transformer forced outage. Transmission line events result in the highest duration of transformer outages for Environmental and Unknown events that remove transformers from service. However, transformers themselves are responsible for about 2/3 of unavailability as a result of Equipment Failure events – even although they cause by far the smallest number of Equipment Failure related forced outages.

Figure 5-8: 10 year Average Durations of Transformer Forced Outages – By Source of Outage



5.5 Frequency of Transformers Planned Outages and Transformer Planned Unavailability

Figure 5-9 and Figure 5-10 show the numbers and durations of planned outages of transformers per 100 transformers in service.

This includes all incidents where a transformer was taken out of service to allow any maintenance, repairs or construction to proceed, as well as other “miscellaneous” planned outages. A planned outage is any outage which has not been classified as forced (i.e. as a result of protection operation or where the transformer is taken out within 24 hours of a problem requiring this outage being discovered).

Figure 5-9 shows the numbers of planned outages for any reason as well as the number that were required for work on the transformer itself. As for forced outages, in most cases there is no resultant loss of service to customers, although they usually result in reduced redundancy at a site and therefore a greater risk of a loss of service for the duration of the outage.

Figure 5-9: Transformer Planned Outage Rates – 10 year Average

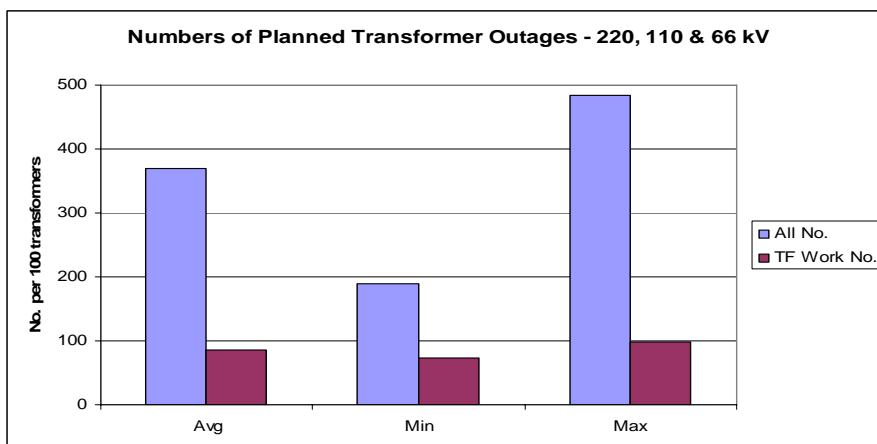
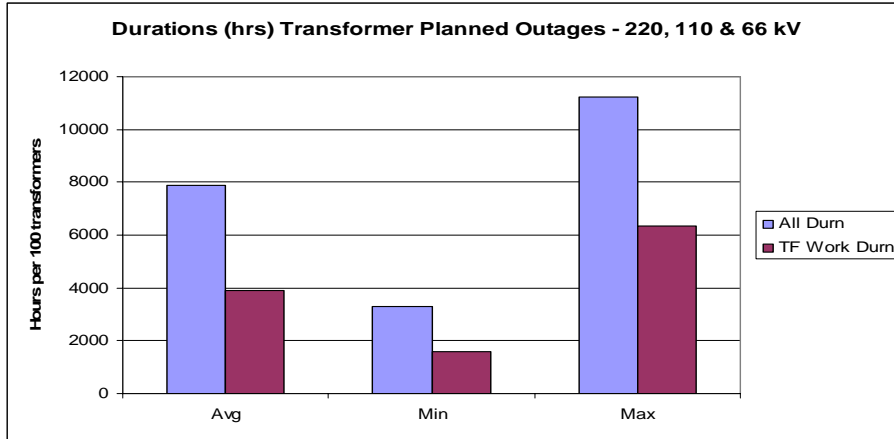


Figure 5-10 shows the duration in hours of the outages displayed in Figure 5-9, i.e. for all transformer planned outages for any reason as well as for outages for work on the transformer itself.

Figure 5-10: Transformer Planned Outage Unavailability – 10 year Average



6 Historical Transmission Circuit Performance – 220 kV, 110 kV and 66 kV

This section provides an overview of the forced and planned outages and unavailability of transmission circuit branches.

6.1 Questions and Discussion of Transmission Circuit performance

Q. 1 Do the measures and analyses provided here provide meaningful information to customers?

Q. 2 In this particular study, interconnected (core grid) and radial (distribution) transmission circuit performance has been combined in the analyses.

Is the same performance criteria applicable to both interconnected and radial transmission circuits or should their performance be assessed separately?

Q. 3 The majority of transmission circuits into Transpower sites are configured to provide at least N-1 security. Therefore, generally the outage of a single circuit does not result in an obvious impact on customers, such as an interruption to, or restriction of, service. However, for the duration of any outage the security will be reduced. Outages may also result in regional constraints

Is the provision of N-1 security, reducing to N security during outages, for transmission circuits adequate going forward?

Q. 4 Restoration times following a forced outage will be affected by the nature of the event, but also by the availability of spare or replacement equipment and/or components and options available to re-configure the grid.

What typical restoration times do customers expect following a circuit forced outage which reduces security?

6.2 Summary of Circuit outage performance

For transmission circuits, the environment and unknown causes are the leading factors driving both frequency and duration of forced outages. The vast majority – well over 90% - of these outages originate on the circuit. Transmission lines are by their nature exposed to a vast range of environmental factors. It is likely that the majority of the “unknown” events are environmental in nature, the distributed nature of circuits often makes it difficult to determine an exact cause for a forced outage.

Planned outages are the main causes of equipment unavailability performance in terms of both numbers and durations of outages. However, as these are pre-arranged, the impact on performance as seen by end consumers is generally minimal (other than for “n” security supplies). Nevertheless, these planned outages increase risk exposure, and may contribute towards interruption events.

Some planned transmission circuit work on main circuit components is carried out using live line techniques, and this reduces the impact on overall circuit performance.

6.3 Frequency of Circuit and Circuit Branch Forced Outages

Figure 6-1, Figure 6-2 and Figure 6-3 show the numbers of forced outages of circuits per 100 circuit kilometres for faults in circuit branches or on other equipment which result in a circuit being removed from service. A circuit branch includes the switchgear, protection and other plant items associated with the circuit.

Figure 6-1 is based on all circuit branch forced outages for any reason. Environmental and Unknown causes are the two most common reasons for a circuit being forced out of service, with Equipment Failure a close third. A high proportion of these outages – about 30% - were momentary only as the circuit tripped and successfully auto-reclosed. Over 60% of all these outages were of 10 minutes or less duration. Circuit outages may be the result of protection operations or a manual operation within 24 hours of a problem requiring an outage being discovered. The Environmental category includes weather related events as well as for example animals, birds, vermin and corrosion.

Figure 6-1: Circuit Branch Forced Outage Rate – 10 year Average, All Outages for Any Reason

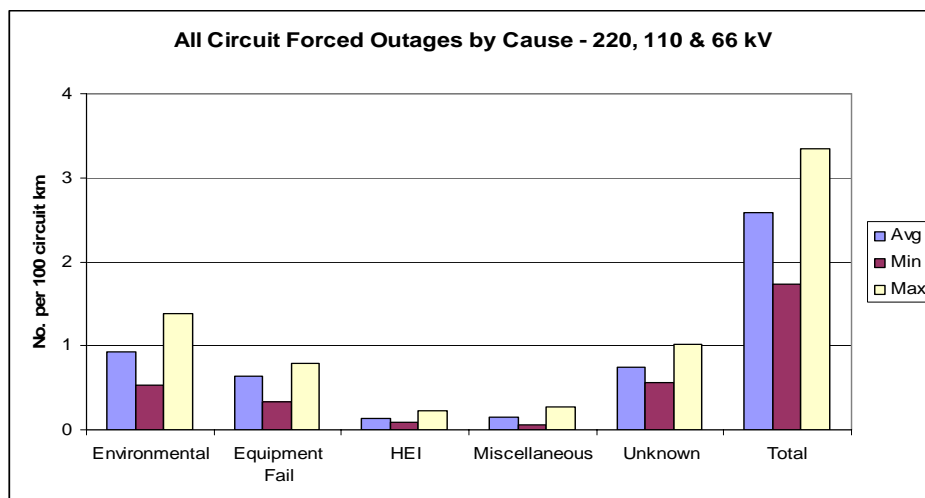


Figure 6-2 is based on circuit forced outages which were caused by events where the circuit itself was identified as the source of the outage. Environmental and Unknown causes are again the leading cause of these outages. The distributed nature of transmission circuit assets makes them particularly vulnerable to environmental impact, and it is most likely that a high proportion of “Unknown” events are caused by environmental factors also. Again, these outages may be the result of protection operations or a manual operation within 24 hours of a problem requiring an outage being discovered.

Figure 6-2: Circuit Forced Outage Rate – 10 year Average, Circuit initiated Outage

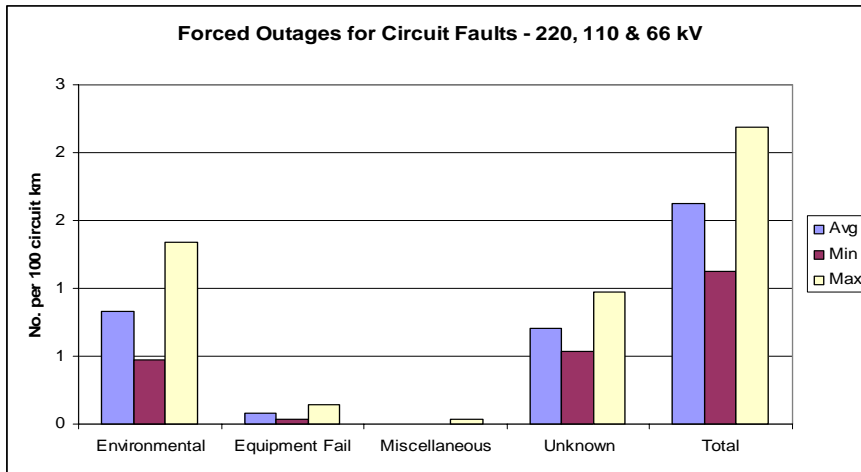


Figure 6-3 is based on the same data as Figure 6-1. However, it shows the percentage of outages in each cause category broken down by the item or source of the circuit forced outage. As noted above, environmental (and “unknown”) factors acting on the transmission circuits themselves cause most of the Environmental and Unknown events that remove transformers from service. Transmission circuits themselves account for only a small proportion of the Equipment Failure events that result in a circuit being forced out of service. The “Other” category includes human errors, unusual system conditions/configurations, and events in customer (generator or distribution) systems that have resulted in a Transpower circuit being forced out of service.

Figure 6-3: All Circuit Branch Forced Outages – 10 year Average, by Source of Outage

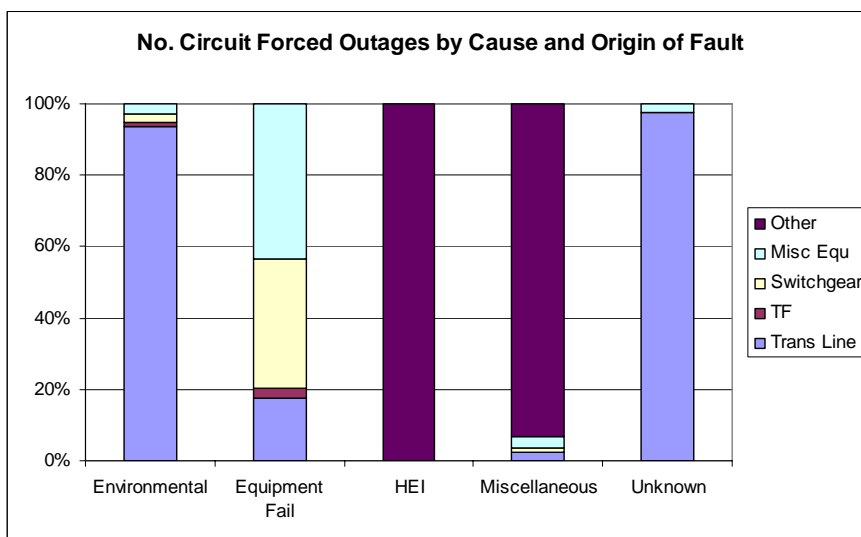


Figure 6-4 and Figure 6-5 give two different views of the distribution of frequency of circuit branch forced outages. Both views are based on all circuit forced outages for any reason.

Figure 6-4 looks at each year for the 10 year period and counts up the number of forced outages on individual circuits. These figures have then been averaged over the 10 year period. In any given year, it is expected that 40% of circuits will experience zero forced outages. Overall, about 60% of circuits in service in any given year will have one or more forced outages. Most – about 49% - will experience between 1 and 3 forced outages in any year. A small number of circuits may experience a significant number of forced outages in that period.

Figure 6-4: No. of Circuit Branches with Forced Outages in any year – 10 year Average, All Outages for Any Reason

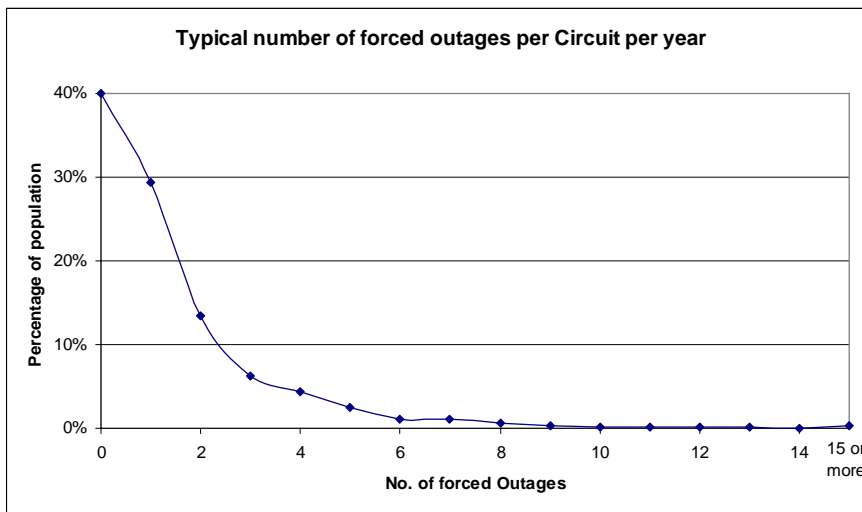
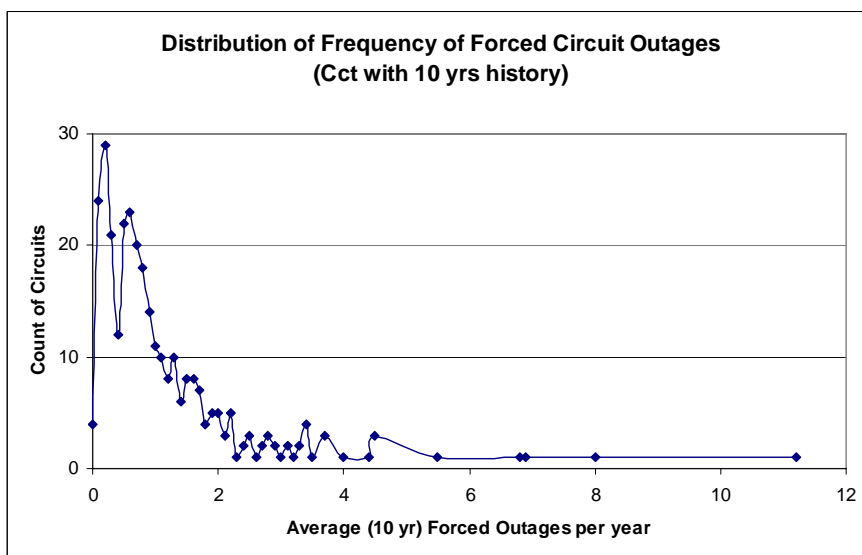


Figure 6.5 shows the average number of forced outages on any given circuit branch over the 10 year period. (Circuits with less than 9 years history in the selected 10 year period have been excluded from these figures). Over the 10 year period a very small number of circuits have experienced no forced outages at all. The majority have experienced less than 2 forced outages per year in that period.

Figure 6-5: Circuit Branch Forced Outage Rate – 10 year Average Forced Outages per year



6.4 Forced Unavailability of Circuits

Figure 6-6, Figure 6-7 and Figure 6-8 show the durations of forced outages of circuits per 100 circuit kilometres.

Figure 6-6 shows the duration in hours of the outages displayed in Figure 6-1, i.e. all circuit branch forced outages for any reason. Although less numerous, outages caused by Equipment Failure have the greatest impact on the durations of circuit outages. These figures are based on individual circuits. Therefore these outages in most cases do not result in losses of service to customers, although they usually result in reduced redundancy at a site and therefore a greater risk of a loss of service for the duration of the outage.

Figure 6-6: 10 year Average Durations of Circuit Forced Outages for Any Reason

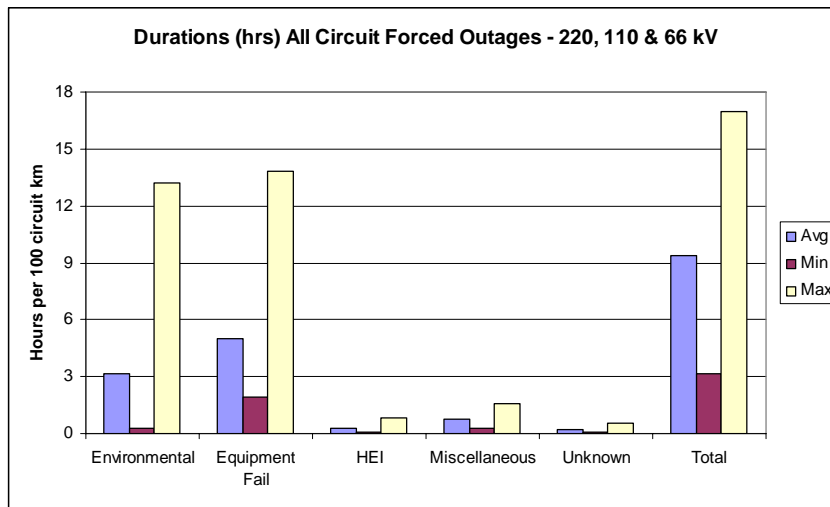


Figure 6-7 shows the duration in hours of the outages displayed in Figure 6-2, i.e. circuit forced outages which were caused by events where the circuit itself was identified as the source of the outage. In this case outages caused by Environmental factors are the main driver for this performance. Of course, while the cause is environmental, there may be damage to the circuit which requires repair, e.g. a conductor damaged by flying debris.

Figure 6-7: 10 year Average Duration of Outages where Circuit issue initiated Outage

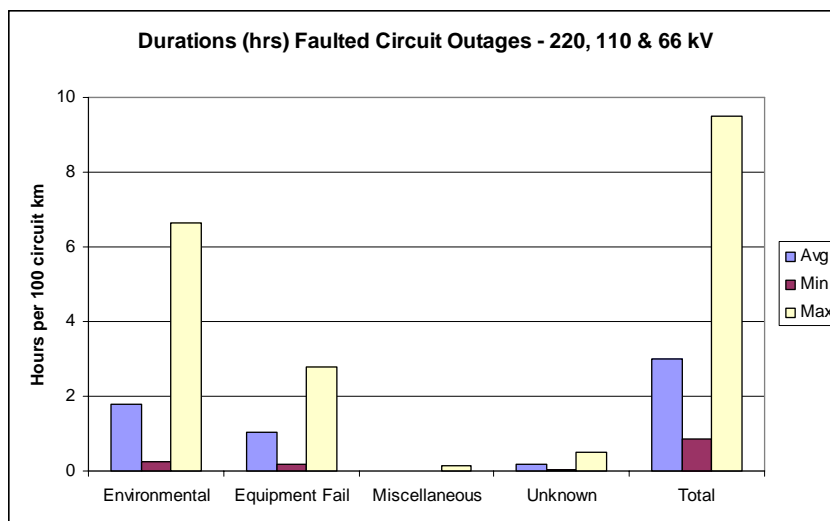
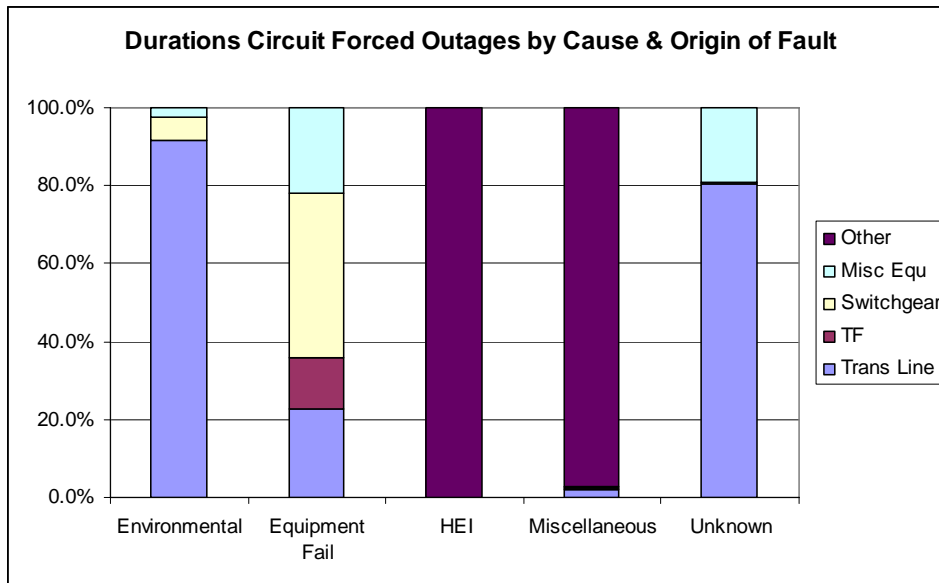


Figure 6-8 shows the duration in hours of the outages displayed in Figure 6-3, i.e. all circuit branch forced outages for any reason. However, it shows the percentage of outages in each cause category broken down by the item or source of the circuit forced outage. Transmission circuits themselves are the main driver in both the environmental and unknown categories. However, they contribute a relatively small proportion of the durations as a result of equipment failure.

Figure 6-8: 10 year Average Durations of Circuit Forced Outages – By Source of Outage



6.5 Planned Unavailability of Circuits

Figure 6-9 and Figure 6-10 show the numbers and durations of planned outages of circuits per 100 circuit kilometres.

This includes all incidences where a circuit was taken out of service to allow any maintenance, repairs and construction to proceed, as well as other “miscellaneous” planned outages. A planned outage is any outage which has not been classified as forced (i.e. as a result of protection operation or where the circuit is taken out within 24 hours of a problem being discovered) on any item of plant that resulted for any reason.

Figure 6-9 shows the numbers of planned outages for any reason as well as the number that were required for work on the circuit itself. As for forced outages, in most cases there is no resultant loss of service to customers, although they do most often result in reduced redundancy at a site and therefore a greater risk of a loss of service for the duration of the outage.

Some transmission circuit maintenance is carried out using live line techniques, and this reduces the number, and the overall duration of circuit planned outages that would otherwise occur.

Figure 6-9: Circuit Planned Outage Rates – 10 year average

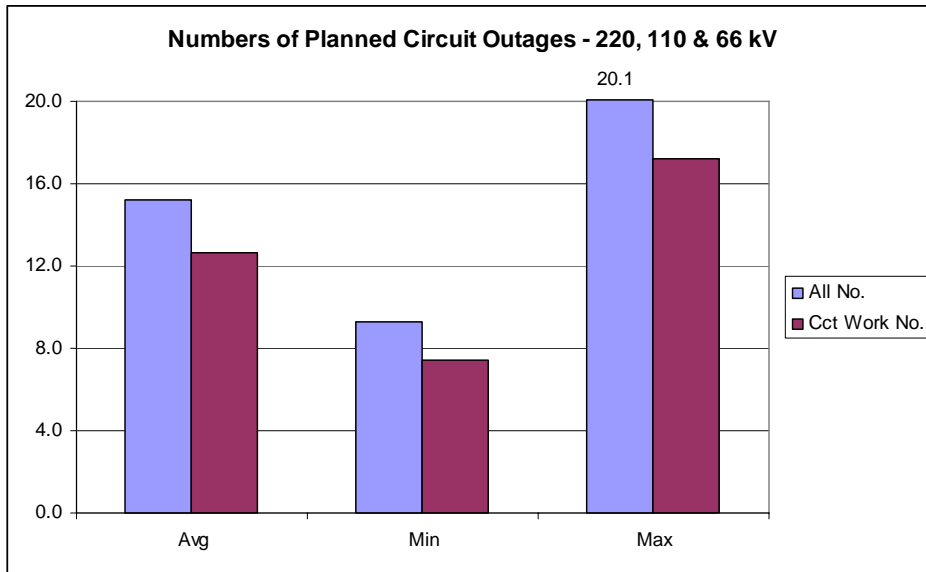


Figure 6-10 shows the duration in hours of the outages displayed in figure 6.9, i.e. for circuit planned outages for any reason.

Figure 6-10: Circuit Planned Outage Unavailability – 10 year Average

