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USE OF DATA FROM CIGRE HIGH VOLTAGE EQUIPMENT RELIABILITY SURVEY

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SUMMARY

When undertaking a survey into the reliability of electrical equipment it is important to consider how utilities/manufacturers/universities apply and benefit from the calculated availability, failure rates and other parameters in the survey.

Electrical networks worldwide have an increasingly aged population of electrical equipment. The survey's application helps the owners and operators of these networks to understand the impact of aged equipment (SF₆ breakers, instrument transformers, GIS, disconnectors and earthing switches) on network performance and helps mitigate the effects through proper operation, effective maintenance, monitoring, asset refurbishment and asset replacement. For new and expanding networks, the survey will help to optimise design and help define operation, maintenance and monitoring of the assets to achieve the desired level of network performance. Additionally the survey will aid in adopting a more statistical approach to asset management including maintenance and replacement.

A review of survey data applications and benefits is described. Two case studies are presented, one for network performance and the other for asset (equipment) performance.

Reliability data from the survey will have numerous uses, both when looking at network and asset (equipment) performance. This data is becoming more important as many electrical networks have ageing assets and many electrical networks are facing increased development.

KEYWORDS

reliability, asset performance, network performance, high voltage equipment, failure statistics

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Introduction

When undertaking a survey into the reliability of electrical equipment it is important to consider how utilities/manufacturers/universities apply and benefit from the calculated availability, failure rates and other parameters in the survey. A summary of survey data applications and benefits is provided by the working group, supplemented with information from CIGRE brochure no. 211 “General overview on experience feedback methods in the field of electrical equipment”¹ and from other CIGRE surveys for high voltage equipment^{2,3}.

General

Electrical networks worldwide have an increasingly aged population of electrical equipment. This survey helps the owners and operators of these networks to understand the impact of aged equipment (SF₆ breakers, instrument transformers, GIS, disconnectors and earthing switches) on network performance and helps mitigate the effects through proper operation, effective maintenance, monitoring, asset refurbishment and asset replacement. For new and expanding networks, the survey will help to optimise design and help define operation, maintenance and monitoring of the assets to achieve the desired level of network performance.

Additionally the survey will aid in adopting a more statistical approach to asset management including maintenance and replacement.

The use of the reliability data from the survey can generally be split into two main areas, either to look at the overall network performance or to look at individual asset (equipment) performance.

Asset (Equipment) Performance

The performance of an asset can be split into the stages of the asset lifecycle. At each stage reliability data can be used to monitor and improve the process by equipment users, manufacturers, regulators or by interested third parties such as universities. An overview of the uses of reliability data is given in Table 1.

The data collected by the survey can be analysed to provide a number of different basic types of statistical data.

Absolute Failure Rates

The data can be used to derive a failure rate, typically the number of failures per 100 years, for a particular family of high voltage equipment. This failure rate can then be used for example at the initial life of the asset to ensure that the application of the high voltage equipment is consistent with the expected failure rate. The absolute failure rate has a number of uses during the operating phase of the asset and for example can assist in determining the optimum number of spares.

Failure Rate with Age

The survey includes questions regarding the age of the failed items and the age profile of the population. This allows the failure rate for different ages of equipment. It should be noted that as designs and maintenance practices change over time it is not possible to assume that any definitive age profile or “bath tub” curve can be found. However with care such information should enable maintenance to be more targeted and should help inform the difficult decision when to refurbish or replace an item of high voltage equipment.

	Building							Operating				Replacing		
	R&D	Specification and standards	Design optimisation	Improved application	Manufacturing and factory testing	Installation and site testing	Life Cycle Costing	Operation	Maintenance	Monitoring	Insurance requirement	Identification of asset replacement / refurbishment	Asset refurbishment content	Asset replacement strategy
Absolute failure rates				x			x	x	x		x			
Failure rate with age							x		x	x			x	x
Comparative failure rate (causes, modes, components)	x	x	x	x	x	x		x	x	x			x	x
Comparative failure rate (location)				x					x	x				x
Comparative failure rate (technological solution)		x	x					x	x	x				
Maintenance information in survey							x		x					
Compare own design / equipment with survey	x	x	x		x	x		x	x	x		x	x	x
User compares overall failure rates with survey		x						x	x					x

Table 1: Summary of Asset (Equipment) Performance Improvements That Typically Can Use Reliability Data

Comparative Failure Rate (Causes, Modes and Components)

The survey will identify failure causes, modes, components that cause the most problems. This can be used for example to improve maintenance and target common failure causes, modes and components.

Comparative Failure Rates (Location)

The failure rates of equipment in different locations, for example indoors or outdoors, can be compared. The results could be used to design future installations or to help direct maintenance.

Comparative Failure Rates (Technological Solutions)

The survey examines the failure rates for different technological and design solutions. Comparing these failure rates will be particularly useful for design optimisation of equipment.

User Compares Own Designs or Equipment with Survey

A user, either a manufacturer or network owner, can calculate the failure rates of their own equipment comparing individual designs or technological solutions and compare these with the survey findings. The results of the comparison can inform the users of weak areas that could be improved.

User Compares Own Overall Failure Rates with Survey

The overall performance of the utility with regards to the reliability of the equipment can be compared with that reported in the survey and may result in a change in maintenance policy or equipment specification.

Network Performance

Network reliability can be modelled by splitting the network into a number of parts (for example circuits and substations) and then further splitting into components (for example transformers, circuit breakers, overhead lines, etc). The reliability of each component can be used to predict the reliability of each part of the network and then the overall network performance.

Typically such studies are of interest to network operators, owners, universities, regulators and suppliers of transmission systems and cover both planned and unplanned outage considerations.

Studies can be made into structures of transmission/distribution networks. Typical studies could be:

- Feasibility and design of new networks or extensions to existing networks
- Analysis of existing network or parts of the networks (for example circuits) to estimate reliability and improve weak areas
- Predict future performance due to ageing of equipment
- Design optimum network and substation configurations
- Network resilience and complexity – to look at the reliability of a network including the ability to take outages for repairs and construction work

These studies can help a network owner to define the capital expenditure requirements for the future.

A brief overview of possible studies is given in Table 2.

	R&D	Specification and standards	Single line diagram and configuration optimisation	New investment optimization	Performance prediction (Key Performance Indicators incl.)	Negotiation with state Regulator	Redundancy requirements identification	Outage planning and coordination
Absolute failure rates	X	X	X	X	X	X	X	X
Failure rate with age	X	X	X	X	X	X	X	X
Comparative failure rate (causes, modes, components)	X			X	X			X
Comparative failure rate (location)	X	X	X	X	X	X	X	X
Comparative failure rate (technological solution)	X			X	X			X
Maintenance information in survey								X
User compares overall failure rates with survey		X		X	X	X		

Table 2: Network Performance Issues That Typically Can Use Reliability Data

Case Studies

Two case studies are presented, one for network performance and the other for asset (equipment) performance.

Investigations of Network Performance

The use of reliability data for complex studies have been published already⁴ and a simple example is shown for this paper. When a user is building a substation there is a number of possible arrangements that can be chosen. In Figure 1, two possible arrangements are shown that perform a similar function.

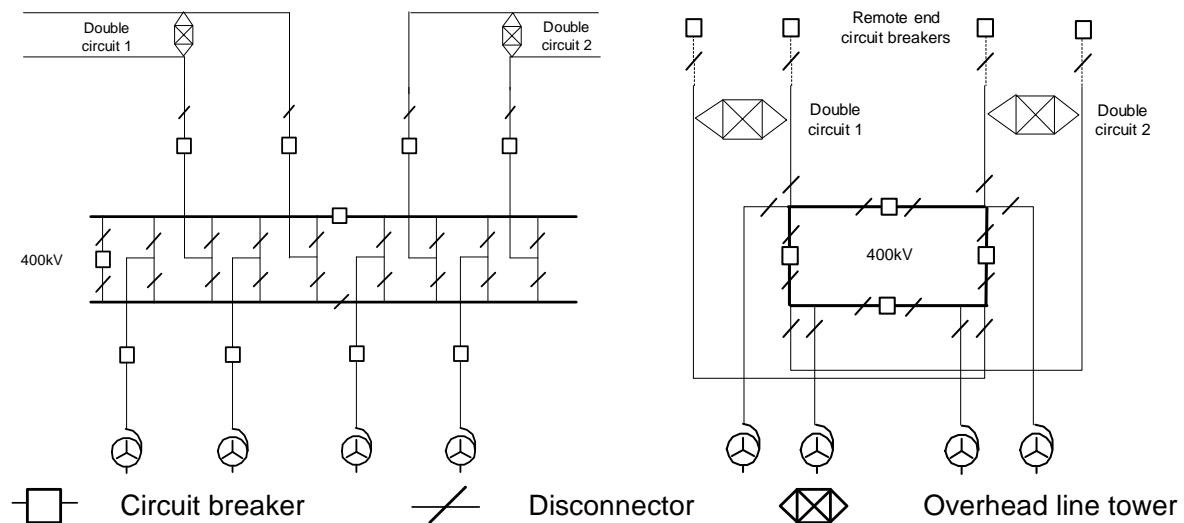


Figure 1: Two Possible Substation Arrangements

While the substation arrangements in Figure 1 perform a similar function, they use a different layout. The layout on the left uses more equipment than that the layout on the right and is likely to be more expensive. However the arrangement on the left is more flexible and should allow for a better network performance.

Each component (circuit breaker, disconnecter, etc) in the substation can be modelled mathematically and the results from the survey can help define some of the model. The circuit availability and reliability can then be calculated for a number of scenarios to estimate the impact of each substation arrangement.

Investigations of Equipment Performance

The second international enquiry on high voltage circuit breaker failures and defects in service³ compared the failure rates of hydraulic, pneumatic and spring operated mechanisms.

	Hydraulic		Pneumatic		Spring	
Failure rate (failures / 100 years)	Major	Minor	Major	Minor	Major	Minor
	0.31	2.9	0.27	0.80	0.27	0.40

The survey suggests that hydraulic mechanisms are the most unreliable and that spring mechanisms are the most reliable. This would encourage circuit breaker designers to use spring mechanisms or improve hydraulic mechanisms and would encourage users to increase maintenance of hydraulic mechanisms.

Conclusion

Reliability data from the survey will have numerous uses, both when looking at network and asset (equipment) performance. The results from the survey will enable improvements in design, manufacturing, operation and replacement of equipment and networks. This data is becoming more important as many electrical networks have ageing assets and many electrical networks are facing increased development. Additionally the survey will aid in the adoption of a more statistical approach to asset management.

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