



# Study Committee C1

Power System Development and Economics

Green Book

Power System Assets: Investment, Management, Methods and Practices

## Outline

### Part 1: The AM foundation

- •Understanding asset ageing
- Asset management functions and interactions
- Regulatory/governmental influence
- Interactions between System development planning and asset sustainment planning
  Risk-based business case development

### Part 2: AM Practices: 12 detailed Case Studies

- •Targeted Equipment Servicing (as an Alternative to Replacement) of Disconnectors
- •Overhead Transmission Line Asset Sustainment Investment
- •Transformer Sustainment Investment Options
- •Substation Reinforcement
- •Transformer Repair/Replace Options

Asset Fleet Management: "Bow Wave" Analysis
Insurance As an Optional Asset Management Investment
Risk-Based Overhead Line Corridor Clearance Management
A New Reliability-Based Planning Measure for Grid Investment Prioritization
Asset Failure Susceptibility Ranking
Probabilistic Risk Assessment for Spare Transformer Planning



Identification of system needs/options -Like-for-like replacements or otherwise Introduction of new technologies with improved functionality

http://www.cigre.org





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#### The book is focused on:

Practical methods to achieve results in the form of smarter asset investment decisions

The synergism or blending of system and equipment know-how, with probability/risk based methods and financial analysis.

Providing sufficient technical and analytical detail at a level comfortable for working level engineers and analysts, with minimal need to search for back-up reference or text book material.

Service Life	Hazard Rate	Cumulative	Density	Point Estimates	
1	1.85736E-08	3.33204E-08	1.85736E-08	Mean 65	
2	3 17135E_08	5.79013E-08	3.17135E-Q8	SD 10 35 0.01 Point estimates as	
		9.96443E-08	5.36104E-08	42 0.012 calculated from meth	od in
Hazard rate =	02/(1-C2)	1.69827E-07	8.97244E <sup>(08)</sup>	Asset life statistics from 50 0.055 section 5.1.3 of TB42	12
5	1.48672E-07	2.86652E-07	1.48672E-07	NGNET/KEMA data	
P(SL)=NO	ORMDOST(A2.5F	\$2,\$F\$3,TRUE)	2.43896E-07		
			3.9613E-07		
8	6.36983E-07	1.30081E-06	6.36983E-07		
9	1.01409E-06	2.11245E-06	1.01409E-06		
1 P	(SL)=NORMDEST	r(A2,\$F\$2,\$F\$3,FA	LSE) \$37E-08	Calibration/Corroboration of Spa	rse Data
1			\$25E-06	0.25	
12	3.85355E-06	8.53991E-06	3.85352E-06	12 C	
13	5.89439E-06	1.33457E-05	5.89431E-06	₹0.2 ·	
14	8.92635E-06	2.06575E-05	8.92617E-06		
15	1.33834E-05	3.16712E-05	1.3383E-05	9.15 - H	Aspard Rate
16	1.98665E-05	4.80963E-05	1.98655E-05		
17	2.91968E-05	7.2348E-05	2.91947E-05	€ 0.1 P	foint.
18	4.24826E-05	0.0001078	4.2478E-05		stimates
19	6.11999E-05	0.000159109	6.11902E-05	2	
20	8.72886E-05	0.000232629	8.72683E-05	Ž 0	
21	0.000123263	0.000336929	0.000123222	6 50 100	
22	0.00017234	0.000483424	0.000172257	Pandan Life (Verra)	
23	0.000238573	0.000687138	0.000238409	service Life (Tears)	
24	0.000326998	0.000967603	0.000326682		
25	0.000443784	0.001349898	0.000443185		
26	0.000596366	0.001865813	0.000595253		
27	0.000793573	0.00255513	0.000791545		

A typical illustration from the Green Book of an annotated spread sheet showing the underlying calculation formulae for fitting sparse failure data to an industry based hazard rate function

## Asset management – A work in Progress

The book attempts to fill a gap in documenting risk-based business case analysis methods

The "Bow Wave" problem, anticipated more than 2 decades ago, is treated in an extensive case study in Part 2



A method to assess and value risk is described in chapter 8 on business case analysis in Part 1. The actuarial method allows monetized risk to be compared with optional Capex/Opex investment costs over a planning period to develop a rigorous risk basis for asset management investments.







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### Green Book

#### Asset management – A work in Progress

"When considering a non-recurring single risk over a defined time period, the risk event has two expected outcomes, either the risk will occur resulting in the full consequence cost or the risk event will not occur resulting in a zero-consequence cost.

For this reason the use of summated risk costs for financial provision over a defined time period works best when there is a large collection of risks. This is because if only a small number of risks are being considered, a financial provision based on summated risk cost will either be larger or smaller than is actually required." [ofgem NGNET Risk Annex discussion] An actuarial method to assess and value risk is described in chapter 8 on business case analysis

in Part 1. The method allows monetized risk to be compared with optional Capex/Opex investment costs over a planning period to develop a rigorous risk basis for asset management investments.

	Α	В	С	D	E	F	G	Н		J	K	L	Μ	N	0	Р
1	GSU Transformer															
2	Service life in 2019		F			Impact cost	s of failure									
2	2		<b>5</b>				519		Rick	Probability						
3	Service life at end of planning period	30		7.017					Aversion	of Impacts						
4	Prob. of failure after planning period	0.8763	3	(/.P1/)		Outage	10000		Neutral	1						
5	Impact Costs (k\$)	\$ 17,250				Installation	3000		Averse	0.03						
6						Engineering	750							Expecte	ed discounted	
						Cost of								premiu	m for no failu	re in
						replacement								piannin	g period = P2	1*B4
7						power	0									
	Equipment Replacement Cost Year	ć 7.000				Cafaty	1000						0 5502			
8	∠ero (k\$)	\$ 7,000				Safety	1000						9.5503	L		
9						Environment Regulatory/	1500						<b>_</b>			
10					•	Investor	1000									
11			( <mark>=88+82</mark>	*(1+B12)		TOTAL	17250									
12	Inflation Rate (		3 / _		<b>b</b>											
13	Discout Rate 0.05		5 / / =	POWER(B17,(1-\$	j\$5))											
14	Start year 2019	2020	0 / / 2021	2022	2023	2024	2025	2026	2027	2028	202	2030	2031	2032	2033	2034
15	Years Ahead		1 / 2	=B16*B18	4	5	6	7	8	9	1	0 11	12	13	14	15
16	Inflated Impact Costs	24978	8 / 25727	20400	27294	28112	28956	29824	30719	31641	3259	33568	34575	35612	36680	37781
17	Probability of Impacts	0.000	6 0.0008	=B19/POW	/ER((1+\$b\$13)	,B15) 0022	0.0030	0.0040	0.0053	0.0069	0.008	0.0112	0.0140	0.0173	0.0212	0.0255
18	Risk Averse Probability of Impacts	0.000	0.0010			0026	0.0036	0.0047	0.0062	0.0080	0.010	0.0129	0.0160	0.0196	0.0238	0.0285
20	Expected Impact Costs	17	7 20	=B21+1/P	OWER((1+\$B\$	13),B15) 74	103	141	191	254	33	431	307	370	872	518
20	Per Unit Discounted Premium		1 1 9524		3 7232	4 5460	5 3295	6 0757	6 7864	7 4632	8 107	74 2JZ 78 8 7217	9 3064	9 8633	10 3936	10 8986
22	Expected Per Unit Discounted Premium	0.000		=B21*B1	0.0050	0.0100	0.0160	0.0244	0.0260	0.0515	0.071	0 0.0000	0.1207	0.1711	0.2200	0.0790
22	Diale Dramaiume	0.0006		=SUM(B20:P20	0)/(SUM(B22:P	22)+M8	0.0160	0.0244	0.0360	0.0515	0.071	9 0.0980	0.1307	0.1711	0.2200	0.2782
23		\$ 256	\$ 256	L.		256	\$ 256	\$ 256	\$ 256	\$ 256	\$ 250	5 \$ 256	\$ 256	\$ 256	\$ 256	\$ 256
24	Present Value of Risk premium	\$ 244	\$ 233	=B23/POWER((1-	+\$B\$13),B15)	\$ 201	\$ 191	\$ 182	\$ 174	\$ 165	\$ 15	7 \$ 150	\$ 143	\$ 136	\$ 130	\$ 123
25	NPV of the Cost of Risk (k\$)	\$ 2,662		IM(B23-P24)												
26			=50	DFI(023.F24)												



### The outlook & need for AM Methods:

The energy transition – increased pressure on grid System resiliency – increased extreme weather events Regulatory activism and scrutiny increasing Complex markets & players looking for positive risk/reward opportunities Efficient, effective asset management methods increasingly important Need to make smart investment decisions quickly

