Probabilistic justification of planning, operating and control solutions

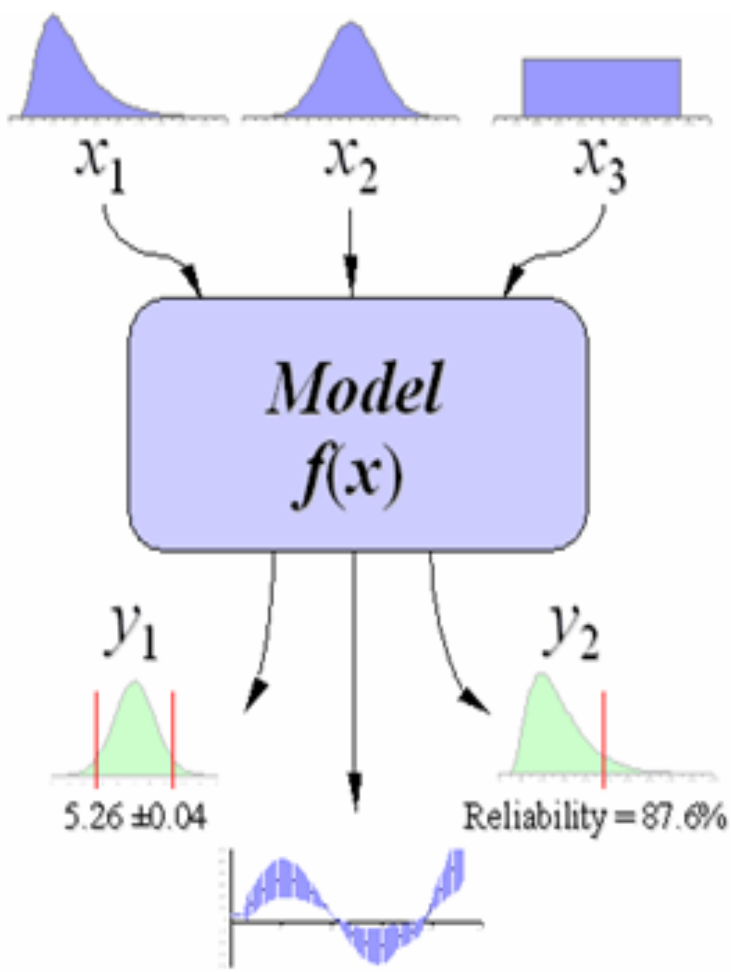
ANATOLIY MEKLIN

QUANTA-TECHNOLOGY, MARCH 2013

Objectives

- 100% reliability ? 🙂
- Reliability improvement → $$$
- Probabilistic studies:
  - verify functionality in wide range of conditions (not only extreme),
  - define long term costs and compare solutions;
  - compliance with a probabilistic standard if available;
  - develop/modify standards
  - …

Monte Carlo Simulation



Step 1: Create a parametric model, $y = f(x_1, x_2, \ldots, x_q)$.

Step 2: Generate a set of random inputs, $x_{i1}, x_{i2}, \ldots, x_{iq}$.

Step 3: Evaluate the model and store the results as y_i.

Step 4: Repeat steps 2 and 3 for $i = 1$ to n.

Step 5: Analyze the results using histograms, summary statistics, confidence intervals, etc.

Task 1. 1983-85. SCADA/EMS based RAS in the North Western region of the former USSR

- Real time steady state contingency analysis for SPS arming
- 0.997 – desirable power flow solution availability
- What if SCADA/EMS data + state estimate?
- *y=f(x)* – modeling of a)topologies of the power and telecommunication systems; b)inability of state estimate to handle loss of data from two adjacent buses
- *x1, x2, x3*…- probabilistic data of telecom. components
- Fortran program for Monte Carlo simulation
- The 0.997 result contributed to the approval of the advanced arming algorithm

www.palisade.com
PALISADE
Maker of the world's leading risk and decision analysis software, @RISK and the DecisionTools Suite
ENGLISH | ESPAÑOL | PORTUGUÊS | FRANÇAIS | DEUTSCH | 日本語 | 中文 | РУССКИЙ
CONTACT US | SUBSCRIPTION | SHARE | FREE TRIALS |
SOFTWARE FOR RISK AND DECISION ANALYSIS
The DecisionTools Suite
&
@RISK
Free Trial Download
Industry Models
SOFTWARE
ACADEMIC
CUSTOMERS
CUSTOM SOLUTIONS
TRAINING & EVENTS
SUPPORT
COMPANY
search site
Search
The DecisionTools Suite
Complete Risk and Decision Analysis Toolkit
» English
» Español
» Português
» Français
» Deutsch
» 日本語
» 中文版
@RISK
Risk analysis software using Monte Carlo simulation for Excel and Project
PrecisionTree
Decision trees for Microsoft Excel
Headlines
New @RISK 6.1 and DecisionTools Suite 6.1 Compatible with Office 2013!
New DecisionTools Suite 6.1 supports Excel 2013, Project 2013, and Windows 8, including 32- and 64-bit versions. In addition, @RISK 6.1 offers a new calculation engine for Microsoft Project schedules that simulates many times faster than before. Upgrade to version 6.1 now.
PricewaterhouseCoopers Advocates "Corridor Budgeting" to Deal with Uncertainties Head On
@RISK plays key role in LEGO's Enterprise Risk Management strategy
Palisade Featured in Healthcare ExecutiveInsight
Conferences and Training
Phoenix
Regional Trainings
Decision-Making and Quantitative Risk Analysis using @RISK
PHOENIX, AZ: Mar 4–5
SOUTH CAROLINA: Apr 3–4
2013 Risk Conferences
SANTIAGO DE CHILE: 19 Mar
SÃO PAULO: 21 Mar
JOHANNESBURG: 25 Apr
TOKYO: 14 May
SHANGHAI: 16 May
LONDON: 11 June
MUNICH: 13 June
LAS VEGAS: 20-21 Nov
Live Web Training
Decision-Making & Quantitative Risk Analysis using the DecisionTools Suite
Part I: Feb 21-22
Free Live Webcasts
Introduction to Risk Analysis using @RISK & The DecisionTools Suite
» March 13
@RISK for Engineers

Task 2. 1998. Justification of the World Bank investment in transmission system development in Indonesia

- *y=f(x)* – power flow model of small power system in Excel; time sequencing of peak, off-peak and intermediate load conditions with different flow patterns.
- *x1, x2, x3*... probabilistic data for T1-time between line/ transformer failures, T2-restoration time. Status is on during T1, off during T2.
- Output – ratio of solved and unsolved power flow cases
- Recommendation was to make investments rather in distribution than transmission system

Task 3. 2000. Simultaneous Forced Outages of Aging Generators in Bay Area

- Objective – to correct "(n-1)&(g-1)" criteria because of increased outage frequency and duration of the aging generators. In 2000, industry FOF=3.8, Bay Area FOF=7.6-30%
- *y=f(x)* – simultaneous status off of transmissions (4 lines, 9 xfrmrs) and generators (30 gens) during each peak hour.
- *x1, x2, x3*… average probabilistic T1 and T2 data for lines/ transformers. PG&E statistical data for 1995-1999 for generators (10-40 status changes for each generator), NERC Gen. Availability Report (GAR) averaged data for comparison
- Simulations with the NERC data gave one occurrence of the (n-1)&(g-1) criteria violation in 45 years. The Bay Area criteria was defined with outage of more than one generator to provide the same frequency of violations.

Task 3. 2000. Simultaneous Forced Outages of Aging Generators in Bay Area (continue)

Probabilities of simultaneous forced outages of generators

# of generators in forced outage	Bay Area data		NERC data	
	% of year	% of year if in peak	% of year	% of year if in peak
>=1	91	8.1	67	5.8
>=2	68	6.2	28	2.4
>=3	40	3.7	8.3	0.72
>=4	17	1.6	1.59	0.15
>=5	6	0.6	0.22	0.03

Probabilities, durations and frequencies of peak hour outages of lines or transformers during forced outages of different MWs of generating capacity

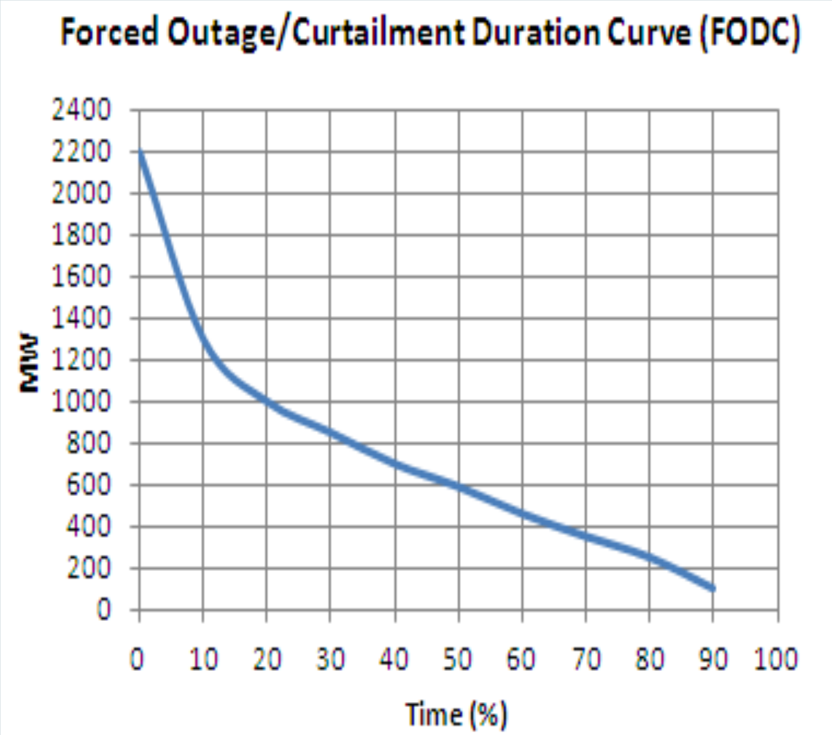
Unavailable MW in forced outage	Bay Area data			NERC data		
	% of year	hrs/year	occurrences/year	% of year	hrs/year	occurrences/year
>=100	0.0157	1.37	0.2 (once in 5 years)	0.00913	0.8	0.104 (once in 9.5 years)
>=300	0.0110	0.96	0.144 (once in 7 years)	0.00548	0.48	0.057 (once in 17.5 years)
>=500	0.0071	0.62	0.092 (once in 11 years)	0.00320	0.28	0.029 (once in 34.5 years)
>=700	0.0056	0.49	0.051 (once in 20 years)	0.00274	0.24	0.024 (once in 41 years)
>=900	0.0033	0.29	0.021 (once in 48 years)	0.00057	0.05	0.008 (once in 125 years)

CalISO Standard for Bay Area, (http://caiso.com/docs/09003a6080/14/37/09003a608014374a.pdf)

CIGRE Technical Brochure on Risk-Based Planning, Working Group 601, 2010

Task 4. 2008. MTBF-based Study of Simultaneous Forced Outages and Curtailments of Generators in Bay Area

- What is new? a) 2003-2008 CalISO data for unit outages and curtailments, b) PG&E Transm. Availability data, c) MTBF reliability criteria, etc.
- MTBF>300 years for Category D regardless of case severity (TPL-001-WECC-CRT-2)
- MTBF would be 300 years for Cat.B due to predominantly light system conditions and mitigations, designed to overcome any MWs of forced outages besides existing less than 13% of time.
- Based on FODC, a critical forced outage/curtailment is 1,190 MW



Distinguishing standard case severities (normal, heavy and forced) would help to define MTBF for categories B and C

Fragment of the performance table from the Russian Guideline

Initial conditions			Disturbance categories, which should not lead to instabilities (detailes about with or without RAS are not in this table)	
Base Case severity	Real power margin in initial case (not used by NERC)	Voltage margin in initial case (not used by NERC)	All lines in service	Line out of service
Normal	0.2	0.15	I, II, III	I, II
Heavy	0.2	0.15	I, II	I
Forced	0.08	0.1	-	-

normal -

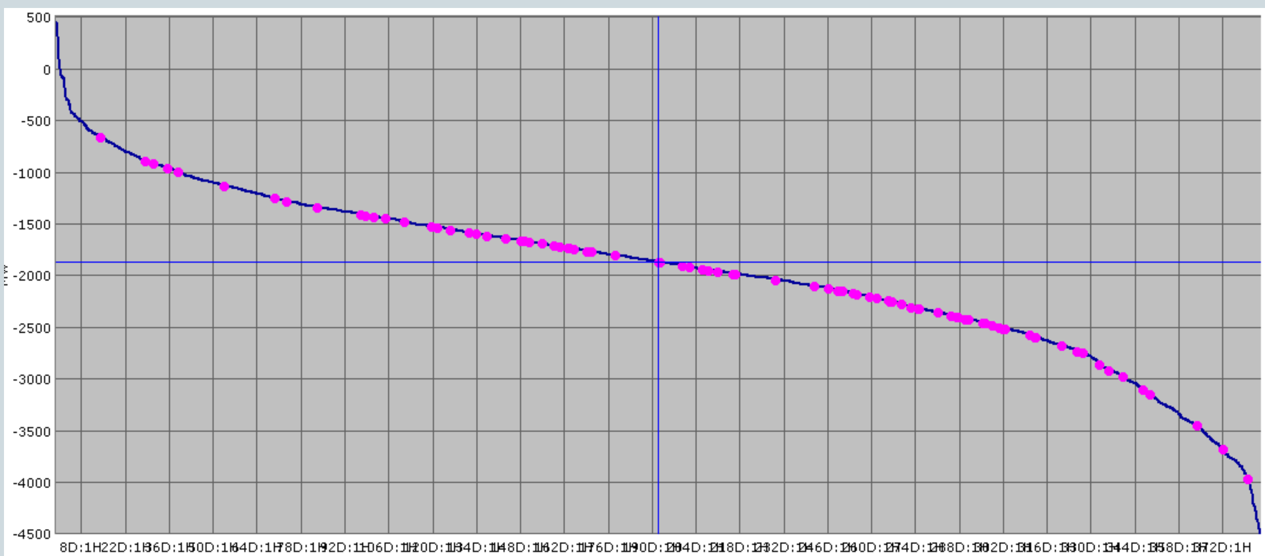
heavy - caused by combination of outages and loading conditions if no longer than 10% of a year

forced - used to avoid load curtailment, loss of hydro resources, nuclear plant run down, etc - **only for operation, not for planning**

I, II, III - similar to NERC categories B, C, D

Task 5, 6. California cost of COI flow reduction

- Task 5. PG&E. 2002. Malin-R. Mnt and R. Mnt-T.Mnt 500 kV line outages, caused by frequent jumper failures.
- Task 6. Quanta-Technology. 2011. T.Mnt-Tesla 500 kV line outages caused by nearby wind turbine blade failures.
- COI energy to be replaced is defined by probabilistic outage simulations combined with variation of COI limits and flows as defined by the historical COI Flow Duration Curve.



Financial Effect of 500 kV Jumper Upgrade

line	# of towers	cost of jumper replacement $	total cost of replacement $	annual cost of replacement $	COI limit w/o the line (MW)	energy cartailment (MWh/year)	BCR	Increm. cost to achieve a given BCR ($/kWh)
Malin-R.Mt #2	15	41120	616800	123360	3200	1000	10	1.234
							8	0.987
							6	0.740
							4	0.493
							2	0.247
							1	0.123
R.Mt-T.Mt #1 & #2	60	41120	2467200	493440	2450	17000	10	0.290
							8	0.232
							6	0.174
							4	0.116
							2	0.058
							1	0.029