Availability Task Force: MTBF Estimation

John Carwardine

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Needed ILC MTBF Improvements

Device	Needed Improvement factor	Downtime (%) due to these devices	Nominal MTBF (hours)	Nominal MTTR (hours)
power supplies	**20**	0.2	50,000	2
power supply controllers	**10**	0.6	100,000	1
flow switches	**10**	0.5	250,000	1
water instrumention near pump	**10**	0.2	30,000	2
magnets - water cooled	**6**	0.4	3,000,000	8
kicker pulser	**5**	0.3	100,000	2
coupler interlock sensors	**5**	0.2	1,000,000	1
collimators and beam stoppers	**5**	0.3	100,000	8
all electronics modules	**3**	1.0	100,000	1
AC breakers < 500 kW		0.8	360,000	2
vacuum valve controllers		1.1	190,000	2
regional MPS system		1.1	5,000	1
power supply - corrector		0.9	400,000	1
vacuum valves		0.8	1,000,000	4
water pumps		0.4	120,000	4
modulator		0.4	50,000	4
klystron - linac		0.8	40,000	8
coupler interlock electronics	[illegible]	[illegible]	[illegible]	1
vacuum pumps	[illegible]	[illegible]	[illegible]	4
controls backbone	[illegible]	[illegible]	[illegible]	1

Have these higher numbers already been achieved?

Tom Himel

Availsim output:
Ranked downtime events by component

comp name	e+ source	e- DR	e+ DR	e- linac	e+ linac	e+ compresso	e- compresso	e- source	e+ BDS	e- BDS	Cryo plants	Site power	Global contro	IP	Grand Total
PS Corrs can tune around beamline	205	194	153	101	113	62	64	47							939
MPS & FastFdbk region	116	41	44			26	25	58	210	206					726
PS controller - corr can tune around b	123	168	171	38	47	35	29	23							634
local backbone sector	48	74	63	97	119	4	9	23	7	8					452
VacV controller beamline	123	42	47	38	44	5	5	12	15	18					349
Electrical - .05<<0.5 Utility power	11	53	53	54	37	3	9	24	4	9					257
coupler interlock electronics coupler	25	0	3	32	13	44	56	27	1	0					201
Klystrons klystron	18	6	7	34	17	46	39	18	3	8					196
Modulators klystron	14			16	10	39	29	18	6	1					133
cryo plant beamline											117				117
other controls klystron	9	4	3	15	4	22	20	16	1	4					98
VacG/Ctrl klystron	14	4	4	12	4	29	19	7	1	1					95
VacP power supply klystron	8	5	5	14	5	23	17	10	4	3					94
Water instr beamline	22	6	8	4	3	4	1	14	16	9					87
MPS & FFWD region				37	44										81
klys pre-amp klystron	8	1	1	7	6	20	28	8	1	0					80
Water pumps klystron	5	4	2	6	3	19	18	9	4	2					72
VacV beamline	29	7	9	13	6	0	2	0	2	4					72
VacP power supply coupler	2	21	32	1	0	7	6	0	0	0					69
Water pumps beamline	20	7	9	3	3	2	2	8	7	5					66
Flow Switch - quads beamline	27	18	20			1	0	0	0	0					66
Water instr klystron	10	2	2	7	4	12	16	7	3	1					64
Q/S Movers beamline	0								31	33					64

Consider four categories of equipment...

- Commodity equipment
  - We buy the quality of service we want (or can afford)
  - eg controls backbone network

Industry

- 'Standard' accelerator components
  - Vacuum pumps, flow switches, circuit breakers, ...
  - COTS parts

Accelerators
+ industry

- Technical systems with large operating base
  - Magnets, power supplies, controls,...
  - Good statistics for reliability estimates

Accelerators

- Technical systems with little / no operating base
  - Newly developed parts, challenging specs
  - Insufficient data for estimating MTBF

Hmm...

Literature search

- There are multiple sources of survey data on power utility reliability, eg
  - IEEE “Gold Book”
  - MIL-HDBK-217
- I have found none about computing / networks.

"Recommended" ETTFs for Power Distribution

MV/LV transformers	: 500 - 1000 years
MV/MV transformers	: 75 - 100 years
HV/MV transformers	: 40 - 70 years
MV and LV circuit breakers	: 1000 - 5000 years
disconnect switches	: 250 - 1000 years
electromagnetic relays	: 250 - 1000 years
electronic relays (single function)	: 100 - 200 years
electronic relay systems	: 10 - 30 years
fuses	: 1000 - 5000 years
voltage and current transformers	: 2000 - 3000 years
standby generators	: 5 - 20 days
probability of fail-to-start	: 0.5 - 2 %
continuous generators	: 1 - 3 years
UPS invertor	: 0.5 - 2 years
rectifier	: 10 - 30 years
underground cables (1000 meters)	: 40 - 75 years
cable terminations	: 1000 - 3000 years
cable joints	: 500 - 2000 years
busbars (one section)	: 500 - 2000 years
large motors	: 15 - 30 years

- Source: M Bollen, "Literature Search for Reliability Data of Components in Electric Distribution Networks"

Power distribution reliability data from in-service surveys (Estimated Times To Failure)

Table 4.5. Reliability of industrial components.[37]

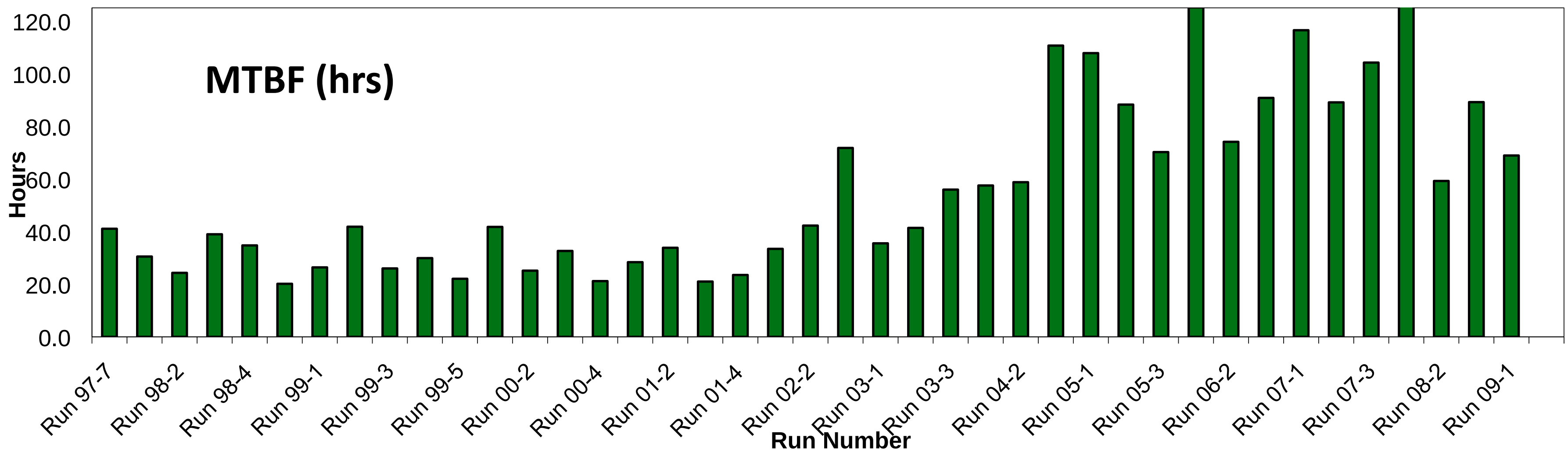
Description	λ_P (per year)			**MTTR** (hours)		
	Low	**Typical**	**High**	**Low**	**Typical**	**High**
Liquid Filled Transformers	0.0053	0.0060	0.0073	39	300	1000
Molded Circuit Breakers	0.0030	0.0052	0.0176	1.0	5.8	10.6
Drawout Breakers	0.0023	0.0030	0.0036	1.0	7.6	232
Disconnect Switches	0.0020	0.0061	0.0100	1.0	2.8	10.6
Switchgear Bus	0.0008[1]	0.0030[1]	0.0192[1]	17	28	550
Cable (not buried)	0.0014[2]	0.0100[2]	0.0492[2]	5.3	7.0	457
Cable (buried)	0.0034[2]	0.0050[2]	0.0062[2]	15	35	97
Cable Terminations	0.0003	0.0010	0.0042	1.0	2.8	10.6

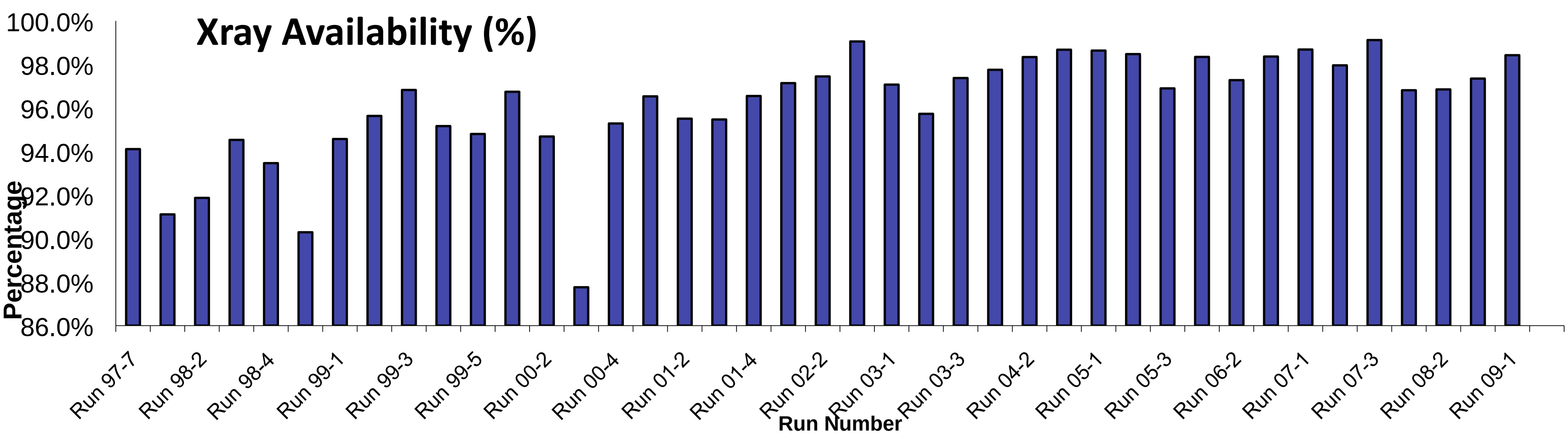
[1]Failure rates for switchgear bus are per circuit foot.
[2]Failure rates for cable are per 1000 circuit feet.

1.6e6 hrs ETTF

- Source:
  - IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems. (IEEE "Gold Book")
- *There are lot's of sources of in-field data on power systems*

APS Run Statistics '97 – '09
(5000hrs/yr, 3 runs/yr)





“Crude estimates” of some MTBFs (APS storage ring)

System	2003	2004	2005	2006	2007	2008	Total	Num units	Unit-hrs	MTBF (khrs)	
PS	18	9	14	4	11	18	**74**	1600	4.0E+07	**541**	Multipoles and correctors are included
Network	2	4	0	1	2	0	**9**	40	1.0E+06	**111**	Assume one network 'system' per sector
Interlocks	16	18	5	8	4	2	**53**	61	1.5E+06	**29**	Accelerator MPS + 40 beamline MPS
Electrical		1	1	0	1	0	**3**	80	2.0E+06	**667**	Assume 2 transformers per sector
Controls	1	8	1	3	2	2	**17**	250	6.3E+06	**368**	Assumes 250 front-end controllers (IOCs)

Crude numbers!

- Numbers represent beam loss events over the year (both transients and failures)
- Total run time is ~30,000 hrs (5000hrs/year)

"There are lies, damned lies, and statistics"

- Suppose 1000 magnets run for 5000 hours and there are 2 failures. What's the MTBF...?

  MBTF = 1000 * 5000 / 2 = 2.5 million hrs

"There are lies, damned lies, and statistics"

- Suppose 1000 magnets run for 5000 hours and there are 2 failures. What's the MTBF?

  ~~MBTF = 1000 * 5000 / 2 = 2.5 million hrs~~

- Failure rate has variance
  - 0 Failures →MTBF = inf
  - 1 Failures →MTBF = 5e6
  - 2 Failures →MTBF = 2.5e6
  - 3 Failures →MTBF = 1.67e6
  - 4 Failures →MTBF = 1.25e6

CBAF Klystron operational statistics

Klystron Reliability Table

Year	Klystron Filament Hrs	Cum Klystron Filament Hrs	Klystron Failures	Cum Klystron Failures	Avg Klystron Fil. Hrs / Failure	Cum Avg Klystron Fil. Hrs / Failure
1990	40,000	40,000	0	0	0	0
1991	150,000	190,000	11	11	13,636	17,273
1992	365,000	555,000	19	30	19,211	18,500
1993	390,000	945,000	12	42	32,500	22,500
1994	700,000	1,645,000	9	51	77,778	32,255
1995	2,268,000	3,913,000	34	85	66,706	46,035
1996	2,187,000	6,100,000	14	99	156,214	61,616
1997	2,546,000	8,646,000	12	111	212,167	77,892
1998	2,626,000	11,272,000	3	114	875,333	98,877
1999	2,277,000	13,549,000	12	126	189,750	107,532
2000	2,424,000	15,973,000	16	142	151,500	112,486
2001	2,538,000	18,511,000	5	147	507,600	125,925
2002	2,032,000	20,543,000	1	148	2,032,000	138,804
2003	2,309,600	22,852,600	12	160	192,467	142,829
2004	2,715,456	25,568,056	13	173	208,881	147,792
2005	2,657,232	28,225,288	3	176	885,744	160,371
2006	2,343,600	30,568,888	7	183	334,800	167,043
2007	2,077,440	32,646,328	14	197	148,389	165,717

- 5KW CW L-band klystrons
- Num.: 42
- Average lifetime: 165,000hrs

R. Walker: 5th High Power RF Workshop: http://cwrf08.web.cern.ch

Intermediate proposal for Availsim

- Power supplies
  - Lump together PS and PS Controller
  - Use MTBF of 500,000hrs for all magnet power supplies
- Magnets
  - We can do it - dealing with water leaks is not a technology issue
- Computers and networking
  - Industry standards for Quality of Service - assume redundancy and fault tolerance – make availability very high
- AC breakers
  - Use IEEE Gold Book for Industrial/Commercial
- MPS, Electronics in general... (need input from Tom)

Operational experience with the RF power amplifiers

SOLEIL SYNCHROTRON

- The two 180 kW solid state amplifiers for CM1 have demonstrated good reliability in operation.
  After ~ 7 500 running hours, only 4 trips :
  - 3 due to human mistakes (a fault in the interlock logic, a wrong manipulation, a cable pull out by accident)
  - 1 due to a failure on preamplifier module
- Although not perturbing for the operation, **56 (out of 1400) modules have suffered from transistor failures in operation; for 10 of them it was the result of a circulator load failing** → solved by adding thermal grease

- **Failure rate < 3.5 % / year → pessimistic, as it includes part of the infant mortality, lack of grease, damages by accident on amplifier 1 → expected failure rate ~1%**
  → longer running periods are required to find out the *actual MTBF*
- **100 available spare modules → turn over : 50 usable in house while 50 under repair**

R&D
- **Upgrading of the 350 MHz design (investigation of other suitable transistors)**
  → Collaboration with ESRF (~ 50 towers of 50 kW)
- **Other freq. : 300 W module @ 500 MHz → 476 MHz (2 x 40 kW for LNLS)**
  90 x 15 kW @ 1.3 GHz → 4^{th} generation LS (ARC-EN-CIEL)