FAILURE STATISTICS OF DESY POWER SUPPLIES IN 1996

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Abstract

The HERA machine delivered good results in 1996. This was possible due to a higher availability of the technical subsystems than in the years before. Here the failures of the power supplies during 1996 will be analysed and a statistic of the failures of the accelerators will be shown. This will be compared to the failures of the last years to see what improvements had the most succes. A preview onto the next changes will be given and the introduction of new tools (software and hardware) will be explained.

1 INTRODUCTION

One of the subsystems in particle accelerators are the magnet power supplies. Due to the large number of components a high reliability is required. This is not only the availability which is the number of failures multiplied by the repair time of the sub-system, but also the number of failures is important in machines with long filling times. In DORIS the beam is filled within a few minutes after the end of repair whereby in HERA not only the repair time of the power supply is important but also the time of refilling the beams and optimisation for the luminosity run. A failure that is repaired in 10 minutes will have a down time of the machine and the experiments of several hours. To detect systematical errors an analysis of the failures of the power supplies at DESY is made annually and will be presented here. By this systematical errors have been detected and eliminated.

2 SOURCE OF INFORMATION

Beside the machine control room operators a technical shift crew of two persons is working in three shifts when the machines are running. This shift crew is responsible for the repair of the power supplies, part of the water cooling system and the rf-high voltage supplies. Each failure that occurs is written into a log book with time, the assumed reason of failure and with a description of the repair action. This material was used as data base. Additional information about the machine status can be found in computer archives and the control room log books. The HERA machine coordinator tracks down the trips as well in combination with beam loss and down time.

3 NUMBERS OF FAILURES

Over the time period from May 15th till December 23rd the shift crew was called 574 times to solve a problem. This is the actual time when the HERA electron machine was commissioned till it was turned off for the winter shut down. The problems to be solved are from simple reset of an electronic up to a several hours lasting repair of the power parts, which is luckily not very often.

The first statistic of this type was made in 1993. That result and the numbers of the last years is shown in table 1.

Table 1: Number of events when technical shift crew had to react.

	1996	1995	1993
HERA	238	248	252
PETRA	114	165	143
DORIS	87	81	184
DESY II / III	43	113	n.n.
transport lines preaccelerators	92	131	n.n.
analysed period	5304 hrs	6720 hrs	n.n.

4 STATISTICS

The availabilty of the subsystem power supply can be calculated by

$$AV = \frac{MT - (NOF * TOR)}{MT} * 100\%$$

with AV = availability
MT = machine time
NOF = number of failures
TOR = time of repair

The average repair time for the power supplies is assumed as 45 min per failure. Pushing a reset button is much shorter whereby the repair in the power parts takes much longer.

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The MTBF mean time between failure of the machines is given by the formula:

$$MTBF\_M = \frac{MT}{NOF}$$

The failure distribution of power supply failures at DESY can be seen in table 2. P and e indicate the proton or electron machine of HERA whereby the e + p is the sum of both.

Table 2: Power supply failures in the machines, Mean TimeBetweenFailure, AVailability

	problems	MTBF_M hrs	AV
HERA e+p	238[*]	22.3	96.6%
HERA p	163	32.5	97.6%
HERA e	84	63.1	98.8%
PETRA	114	46.5	98.3%
DORIS	87	61	98.7%
DESY II / III	43	123.3	99.4%
transport lines preaccelerators	92	57.6	98.6%
entire DESY	574	9.2	91.9%
analysed period	5304 hrs		

The availability in table 2 includes all failures that appeared and is just the availability of one subsystem. It does not give the number for the performance of the machine. In comparison the actual time between two beam costing failures due to power supplies in HERA is 56 hours.

MTBF of the power supplies in the machines

$$MTBF = \frac{MT * NOPS}{NOF}$$

with NOPS = number of power supplies

Here two numbers are calculated. One is the overall value including every fault that appeared and the power supply was turned off. The second value is with only the problems of the power supply. External interlocks and failures as grid disturbances have been substracted.

Table 3: MTBF of the power supplies

	Number of PS	MTBF_PS overall	MTBF no external failures
HERA e+p	1166	25985	29310
PETRA	269	12515	13988
DORIS	93	5669	8968

5 KATEGORIES OF FAILURES

The data material was sorted to the failures of the machines and categorised. The categories are:

1) unknown -failures that could not be sourced down
2) work induced -due to work a failure was produced
3) single interlocks -interlocks from exterior eg. thermoswitch of magnet. (not really failure but turn off of the supply)
4) Electronic malfunction -error that is due to a malfunction of electronic without a physical failure in the electronic
5) Electronic component -a physical failure in the electronic or survey elements
6) ELS -electronic protection in the choppers. The voltage drop over the MOSFET transistors in the switched mode supplies is monitored. In case of short circuit or break down of a transistors this turns the power supply off. (one of the major problems in HERAe in 1995)
7) Shorts to ground -low impedance to ground within the magnets or the power supplies
8) Semiconductors, fuses -failure of the power semiconductors eg. SCRs, diodes and power fuses. A 100 mA fuse would be an electronic component.
9) mechanical switches - contactors, circuit breakers and polarity switchers
10) PSC, controles -power supply controllers, programmable logical controllers, main computer in the control room
11) transformers -transformers, chokes etc. also the circuit breakers for the transformer protection
12) connections -bad connections of circuitboards, plugs up, bad soldering points, bad screwing of copper bars
13) water cooling plant - failures in the cooling system. An error causes several power supplies to trip
14) water/air cooling in the supplies - only the supplies of one water circuit trip. One to maximum four supplies of the choppers.

6 FAILURES IN THE MACHINES

When looking at the failures each machine has it´s own pattern of failure due to the different types of supplies and also the age of the units. The failures can be seen in table 4.

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[*] Please note that the sum of failures of HERA e + HERA p is higher than the value of HERA e+p. Grid disturbances were conted for both machines. In the sum only one event is counted per machine

Table 4: Failures in the machines

	HERA e	HERA p	PETRA	DORIS
unknown	1	4	0	1
work	0	4	1	2
Single interlocks	11	8	3	21
Electronic malfunction	11	21	21	22
Electronic component	2	6	24	5
ELS	14	5		0
Short to ground	0	4	2	0
Semiconductor, fuses	0	0	3	0
mech. switches	9	71	4	0
grid disturbances	9	9	9	9
PSC, controls	4	22	8	4
Transformers	0	0	0	0
connections	7	4	14	5
Water cooling plant	1	2	1	2
Water, cooling	4	3	10	6
correctors	12	0	14	8
sum	85	163	114	84

HERA p

Still a systematic failure is in the system. The problem is the mechanical polarity switcher of the chopper supplies. The auxiliary contacts of the contactors become high resistive. During polarity switching the magnet is shorted by the switch. A build in electronic waits for this status to continue which due to the bad contacts will not be detected. The polarity switcher stops in the middle of the action.

HERA e

No really overwhelming problem is seen in these statistics. Systematic errors appear to have been eliminated, leaving random errors to be dealt with. The largest problem of the last year, the aging of MOSFETs, has been eleminated by exchanging the MOSFETs.

PETRA

The year was good. The major problems of the previous year been eliminated. Still the number of damaged electronic components might be a sign for the aging of the power supplies.

DORIS

The power supplies worked well this year. The number of failures is constant to the previous year, whereby one quarter of the failures were turn offs by external interlocks. The electronics problem was mainly to one power supply where the failure was extremly hard to find.

DESY II / III

The number of failures decreased rapidly. In 1995 it was a problem with a bad contact of a high voltage switch. The problem was fixed.

BEAM TRANSPORT LINES

Here the number of failures decreased with only routine maintenance.

7 NEW TOOLS FOR MAINTENANCE

When looking at the investment and operating costs of accelerators the demand for short maintainance period and long runs gets stronger. This is usually in contradiction to the technicians view who wants to maintain the power supplies for a failure free next run. Therefore new methods and tools have to be found to decrease the time of working at the units with the same amount off quality.

One fairly simple attempt was made to control the accuracy of the supplies. By a computer program a group of power supplies is driven with a slow ramp procedure and the data of the monitored current is stored. With an EXCEL-spreadsheet this data is visualized. Errors in the Digital/Analog Converter (DAC) or the DigitalVoltMeter (DVM) can easily be detected. This program is used also to control suspicious power supplies during ramping of HERA .

In 1997 an infrared thermo camera will be taken to supervise the power supplies. By this it is possible to check connections and operation of power parts during normal run conditions of the accelerator. On a vendors presentation of such a camera some bad connections where found. This promises good results.

8 SUMMARY

When comparing the numbers of the events the last year did not look much better than the 1995 year though the impact of the failures to the machine run time was smaller. The supplies had more failures during turning on time or massage times than during the actual run time. These failures have to be solved in the next shut down. For several machines the obvious systematic errors seem to be eliminated. The consequence is that the future failures have to be investigated even closer to guarantee a better run.