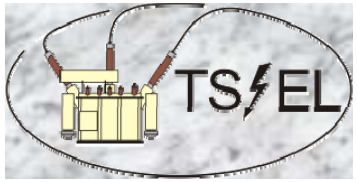
Review of MTTR and spares parts policy in TS-EL

F. Rodriguez-Mateos



MTTR – definition

- This overall performance indicator is calculated by simply considering the time during which the *injectors* are not available for scheduled physics...

- However, it is too general, as most repair interventions usually comprise multiple activities and actions. To enable the assessment and to possibly improve the total quality of the maintenance management activities, the MTTR can be divided into more meaning-full sub-indicators.

"LHC Equipment Maintenance Policy and Requirements"
T. Pettersson, P. Martel
Workshop Chamonix XIV, 2005

- MTTR1 – Production reactivity
  - Users' motivation. Communication channels with the maintenance (have they access to the CMMS*?). Knowledge and adequacy of the existing procedures.
- MTTR2 – Maintenance reactivity
  - Workers' motivation. Organization: is there a helpdesk or a way to contact the responsible? Enough manpower? Adequacy of existing procedures.
- MTTR3 – Manpower availability
  - Number and competences required. Visibility and planning tools. No preventive maintenance = overwork peaks
- MTTR4 – Diagnostic delay
  - Access to technical documents. Asset maintainability or complexity. Particular skills may be required.
- MTTR5 – Preparation delay
  - Organization of the Maintenance Responsibility Center and competences. Relationship with contractor.
- MTTR6 – Stock logistics delay
  - Logistics delays and buying procedures. Identification of critical and strategic stock
- MTTR7 – Purchase logistics delay
  - Supplier identification. Purchase procedures. Integration of CMMS with purchasing systems?
- MTTR8 – Actual work duration
  - Tools, transport, competences
- MTTR9 – Administrative delay
  - Document flows and delays

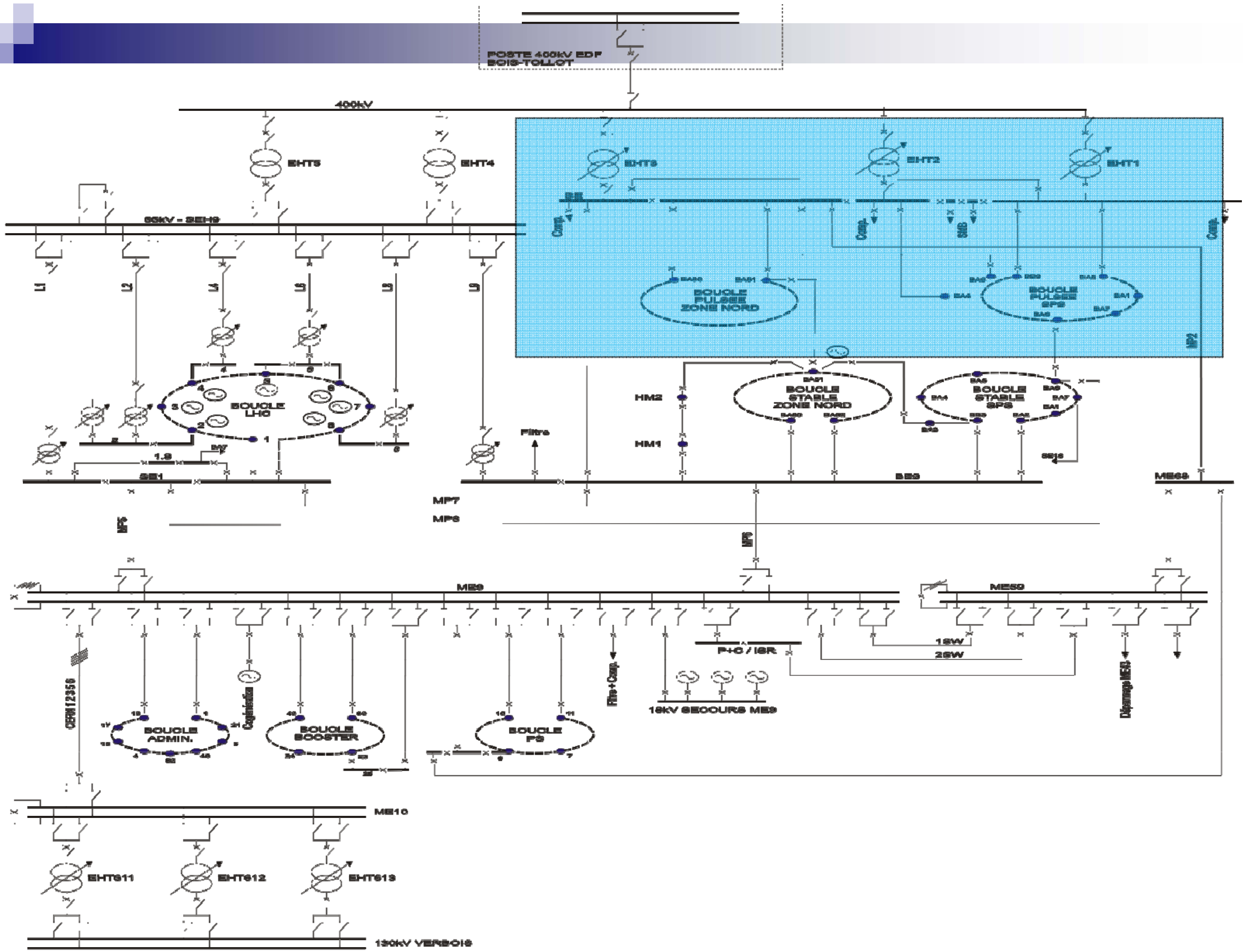
* *Computerized Maintenance Management System*

Outline

- Short introduction to the CERN electrical network principles
- Recent (and not so recent) statistics and TTRs
- Guidelines for alleviation of TTR:
  - CONSOLIDATION
  - MAINTENANCE
  - STAND BY TEAMS
  - SPARE PARTS
  - STOCK MANAGEMENT
- Conclusions

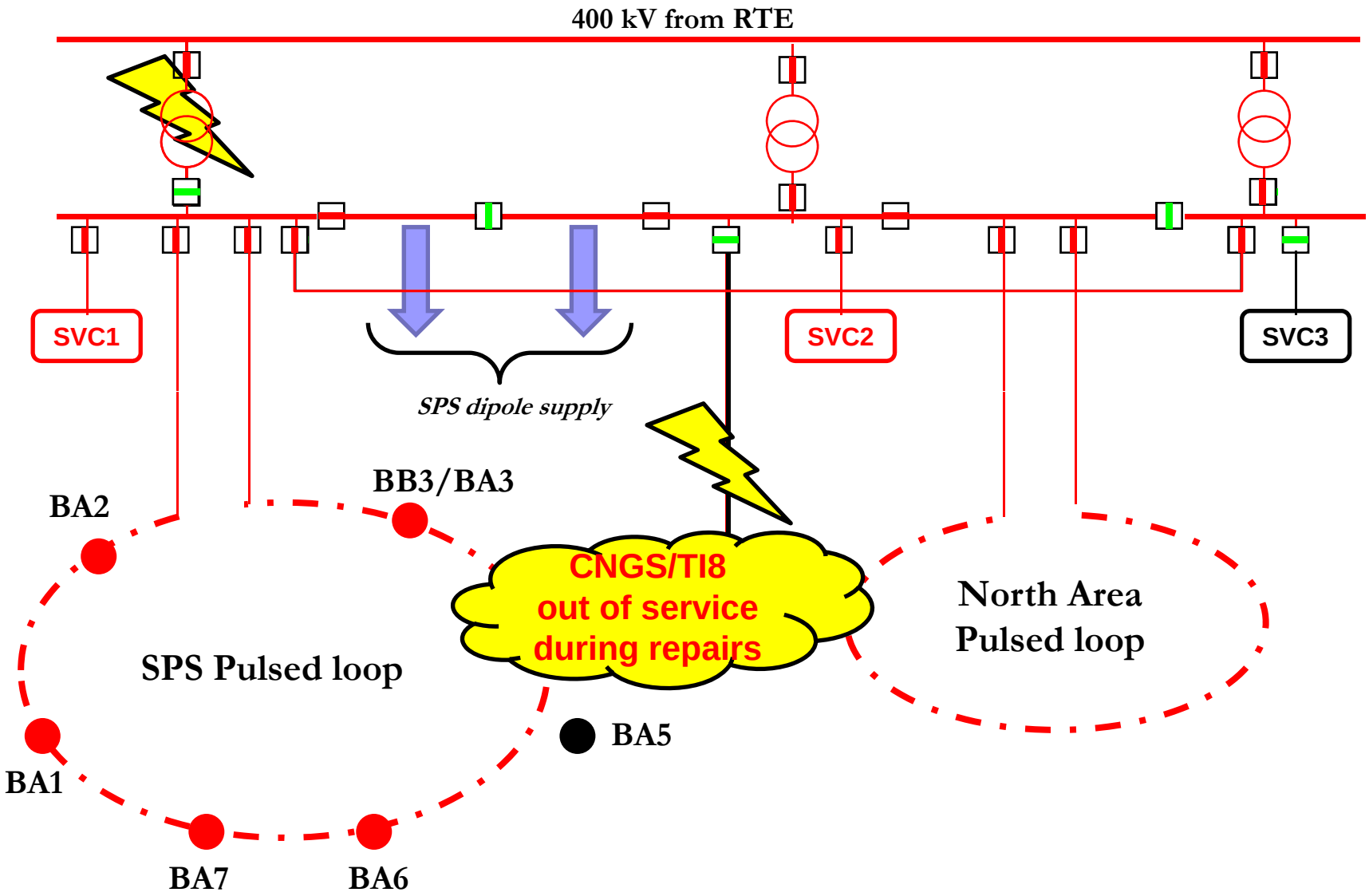
The design-integrated principles for minimizing “MTTR”

- Re-powering by reconfiguration of the network. This implies an existing n+1 redundancy. It is the case for:
  - 400kV power transformers and breakers
  - SVCs in BE
  - most of the cables in SPS
  - 18 kV inter-site links
  - 48V safety control systems
- Repair/replacement of equipment there where no n+1 redundancy exists
  - Transformers, many UPS, HV and LV breakers, the SVC for the LHC even points and Meyrin site, filters, capacitors, PLC, etc…
- Single point failures (a few examples)
  - Incoming 400 kV line
  - 38 MVA Transformers
  - 66kV Cables
  - 18 kV Cables for the pulsed BE-BA4 link
  - Bus bar failures in HV or LV switchboards



POSTE 400kV EDF
BOIS-TOLLOT
400kV
EHT5
EHT4
EHT3
EHT2
EHT1
66kV - SEH9
BOUCLE PULSEE ZONE NORD
BOUCLE PULSEE SPS
BOUCLE LHC
BOUCLE STABLE ZONE NORD
BOUCLE STABLE SPS
HM2
HM1
Filtre
SE1
SE9
ME68
MP7
MP8
ME9
ME59
P+C / ISR
18kV SECOURS ME9
BOUCLE ADMIN.
BOUCLE BOOSTER
BOUCLE PS
ME10
EHT611
EHT612
EHT613
130kV VERBOIS

Redundant and Single Point Failures in SPS



Statistics and TTRs

Statistics for the electrical infrastructure between 2001 and 2007

Main systems concerned	*Major Events*	*Total h for EL*
Compensators and filters	24	~ 63 h
HV breakers	8	~ 80 h
Cables	12	~ 32 h * (+ 40 h)
Transformers	8	~ 18 h

* Reconfiguration time

References

- **EDMS Nr. 692527 “Les Evénements ayant causé des Pannes Majeures entre 2001 et 2005 au PS et SPS : Analyse et Recommandations”**
- **EDMS Nr. 759001 “TS-Note-TS OPERATION REPORT 2005”**
- **TS majors event reports 2001 -2007**
- **TS/EL Reports**

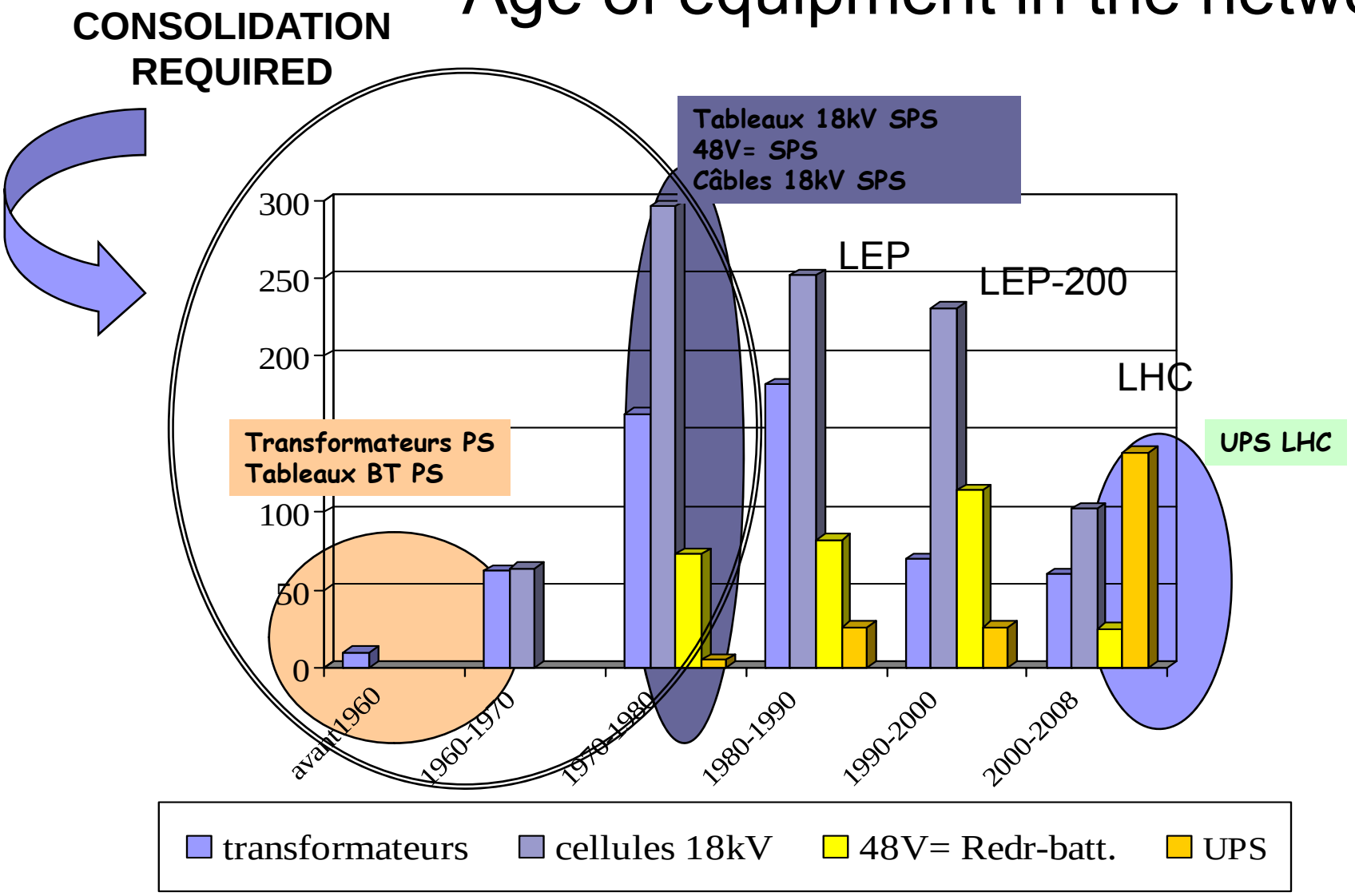
Main events for TS-EL in 2007 already presented by Serge Deleval

TTR in the most severe cases

Failure	When	TTR
Incoming 400 kV line: Explosion of the breaker at the level of BE	August 6, 1993	23h00
Transformers 38 MVA LHC P6: Problem on tap changer	In 1994	72h00
Short circuit in bus bars of 18kV, 3.3 kV or LV switchboards	July 29, 2006	11h20
	June 22, 2006	4h50
	April 10, 2006	13h56
	June 18, 2005	5h45
	October 3, 2003	4h40
	August 29, 2001	24h00
Cable short circuit between BE-BA4	May 27, 2007	40h00

Consolidation

Age of equipment in the network



Risk register as included in EDMS no 855070 (“Plan de consolidation du Resea Electrique du CERN”)

Tableau III. Budget du programme de consolidation réduit *(2008-2011)* par année

Description	2008	2009	2010	2011	TOTAL
Sélectivité réseau	0.2	0.4	0.4		**1**
PS consolidation		0.5	0.5		**1**
SPS consolidation	1.3	1.3	1.3		**3.9**
Provision cables 18kV	1		1		**2**
LHC consolidation	0.5	0.6	0.6	0.3	**2**
Transfo. 66/18kV		1.5	1.5	2	**5**
Spares parts	0.8	0.2			**1**
Divers	0.3	0.3	0.2	0.2	**1**
Consolidation SCADA	0.3	0.4			**0.7**
TOTAL Consolidation	**4.4**	**5.2**	**5.5**	**2.5**	**17.6**

[MCHF]

Description	Prob. de l'éven.	Impacte Physique	MTTR	CERN Reputation	Finance	Safety Envmt	Risk score
SPS Compensateur SVC3	4	4	x 3 (1 an)	2	2	1	48
LHC compensateurs	3	3	x 2 (6 mois)	3	2	1	27
Meyrin filters 18kV	2	4	x 2 (6 mois)	2	1	1	16
Sélectivité réseau							
Relais de Protection et PLC's	3	3		5	1	1	15
PS consolidation							
Tableaux BT PS	2	3	x 1 (3 mois)	2	1	5	10
Tableau secours ME23	2	1	x 1 (3 mois)	2	1	5	10
Distribution BT Tunnel PS	3	2	x 1 (2 mois)	1	1	5	10
SPS consolidation							
Cables enterres 18kV	4	2	x 2 (9 mois)	2	2	1	16
Cellules 18kV Magrini	2	4	x 2 (6 mois)	3	2	1	16
Distribution 48V	2	2	x 1 (2 mois)	2	1	3	6
Relais Protection CEE	3	2	x 1 (1 mois)	1	1	1	6
LHC Consolidation							
48V batteries	4	2	x 1 (3 mois)	2	1	5	20
Convertisseurs 48VDC/230VAC	3	1	x 1 (2 mois)	2	1	5	15
Oscillostores	4	1	x 1 (3 mois)	3	1	1	12
Obsolete UPS LEP	2	2	x 1 (3 mois)	2	1	5	10
Spare parts							
UPS	4	3	x 1 (3 mois)	2	1	1	12
Disjoncteurs HTA	4	3	x 1 (3 mois)	2	2	1	12
Transformateurs	3	4	x 1 (6 mois)	2	1	1	12
Compensateurs	2	3	x 1 (6 mois)	2	2	1	6
Tableaux BT	1	2	x 1 (2 mois)	2	1	1	2
LHC HTB transformateurs							
Transformateur 400/66kV	1	5	x 3 (2 ans)	3	3	1	15
Transformateur 66/18kV	1	5	x 3 (2 ans)	3	2	1	15
SCADA consolidation							
SPS	2	0	x 1 (3 mois)	1	1	1	2
Zone Nord	2	0	x 1 (3 mois)	1	1	1	2
ME4, ME59	2	0	x 1 (3 mois)	1	1	1	2
Divers							
Systemes AUG's	3	1	x 1 (1 mois)	2	1	5	15
Tableaux BT unsafe	3	2	x 1 (3 mois)	1	1	5	15
Meyrin diesel tours refroid.	2	0	x 1 (5 mois)	2	1	5	10
Tableaux BT administrative	2	0	x 1 (3 mois)	1	1	5	10
48 VDC Hall AD ME49	3	2	x 1 (2 mois)	2	1	5	15
Meyrin consolidation							
ME9 Jura (JdB court -circuit)	2	2	x 2 (9 mois)	2	2	1	8
ME10	2	2	x 2 (7 mois)	2	2	1	8
ME59 SW	2	1	x 2 (6 mois)	1	1	1	4
Zone Nord consolidation							
Cellules 18kV Magrini	2	2	x 2 (6 mois)	3	2	1	8
Relais Protection CEE	3	2	x 1 (1 mois)	1	1	1	6
Distribution 48V	2	2	x 1 (2 mois)	2	1	3	6

Maintenance

Maintenance

- Estimation at present of the installed and maintained infrastructure

  > 350 MCHF

- Evolution of the maintenance budget

- Maintenance performed via either running contracts or direct orders

- Applied types: fundamentally corrective and preventive

Year	MCHF/ y *
2001	1,70
2002	1.70
2003	2.10
2004	2.50
2005	2.30
2006	2.90
2007	3.45
2008	3.60

* Include: maintenance contracts, materials and components, expenditures for unforeseen events

Maintenance contracts

- Maintenance contracts are established in a common manner, trying to keep the same structure and the same follow up integrated in D7i

- Reactivity
  - Procedures and QAP well established before hand
    - Feedback from interventions incorporated as soon as possible
  - Factors to be considered when optimizing reaction time with contractors:
    - Assistance (hot line), permanent availability of personnel, qualified personnel with the required certificates, registered in advance

- Technical follow-up
  - Technical specifications must be prepared with a lot of care (it takes time!!!)
  - List of instructions, list of materials and routines as well as stock management must be well defined beforehand
  - Full traceability of actions in GMAO's ODMs (history, statistics)
  - Waste management (ISO 14002)

Maintenance Contracts

Contract	Description	Contractor	Management and follow up	End of contract	Yearly Scope [MCHF]
E067	**Maintenance of Diesel Generator Sets**	RAMS	D7i	31-12-2008	0.150 (new diesels to be included)
E076	**Maintenance of UPS MGE**	MGE France	D7i	31-12-2008	0.200 (new contract being prepared to include APC and Chloride units)
E077	**Maintenance of LV switchboards**	Hazemeyer	D7i	30-06-2009	0.130 (ABB switchboards not included)
E078	**Maintenance HV/LV switchboards**	Schneider	D7i	30-06-2009	0.330
B1115	**ENS servers HW and SW maintenance**	Efacec	(no ODM)	31-05-2013	0.140 (for 5 years)
E091	**Lighting and LV installations maintenance (48V, transformers, switchboards, …)**	SPIE	D7i	30-08-2012	1.2

Maintenance running without contractors, by orders

Description	Status
400kV/66kV Main station Filters and Compensators	Several companies intervening. In 2007, 0.57 MCHF
Protection relays	Contract to be prepared
Oil treatment and corrective maintenance transformers	Id.

Stand-by teams

TS-EL Stand-by teams

- LEVEL 1 Stand-by team
  - 2 staff members from three different sections in the group (BT, HT and OP)
  - for the three zones Meyrin - SPS - LHC
  - the mandate is given in an approved EDMS document n° 608382
  - 15 persons participating
  - 365 days/year, from 17h to 8h and from 12h to 13h in normal working days
  - time to get on site is a maximum of 45' , with start-up of interventions 1h00 after the fault
    - This time can be improved if one CCC-TI operator could accompany the first person arriving on site
- LEVEL 2 Stand-by Engineer
  - 1 engineer guarantees this service
  - for the three zones Meyrin - SPS - LHC
  - this has been put in place following the request of the DH (conclusions to the DG after event on 29/07/06
  - Three persons participating. It is by far not enough and the service is given on best effort basis
  - Technical assistance, management of major crisis from the CCC
- TS-EL-CO "unofficial stand-by team" guarantees a 7d and 24h intervention in case of problems/faults on the ENS main components (servers, concentrators/RTU).

Interventions of the stand-by service

- Number of annual interventions
  - 2002 = 149
  - 2003 = 166
  - 2004 = 136
  - 2005 = 186
  - 2006 = 395 (installation LHC)
  - 2007 = 250

- Nature of interventions
  - Basic interventions (re-sets, re-powering) = 50%
  - Basic equipment failures (replacement of components, UPS rearming) = 30%
  - Scheduled Operations activities outside of normal working hours = 10%
  - Standard faults (AUG, 18kV capacitors, …) = 10%
  - Major failures (short-circuits, auto-transfer, triggers on EDF/SIG, …) < 1%
  - Exceptional interventions with multiple failures < 1%

Situation of major spares

Spare Power Transformers

- Existing
  - 110 MVA x 2
  - 90 MVA x 3
  - 70 MVA x 2
  - 38 MVA x 5
- No spares
- Subject to Consolidation Studies

- A single failure of 110 MVA, 90 MVA or 70 MVA can be remedied by back-feeding or re-busing
- A double failure would compromise the CERN's mission for approximately 2 years

- Single failure of any 38 MVA transformer stops the LHC operation for 2 years (see EDMS 812542)
- Most logical way to avert the LHC shutdown is to purchase a new 70 MVA transformer and replace the 38 MVA transformer in LHC Point 4
- Move the 38 MVA to LHC Point 6 or 8 (similar arrangement to LHC Point 2)

Spare Distribution Transformers

- No spares for all types
- Number and power ratings of spare units will depend on
  - analysis of transformer loading (temperature of insulation)
  - Mechanical loading (pulsed or steady)
  - Function and location of the transformer

Spare HV Breakers

- No spares, just spare parts
- All 400 kV and 66 kV equipment needs to be reviewed, existing spares catalogued, crated and stored in an adequate conditions (warehouse)
- Unauthorized storage on the Prevessin site must be addressed
- New set of 400 kV or 66 kV breakers needed if industry doesn't support existing equipment (ok for the time being)
- Subject of Consolidation Studies

Spares for SVCs

- A new SVC3 to be operational in week 6
- A “hot spare” – SVC1 to be maintained in full readiness until further notice
- Spare parts are defined/being or have been purchased for all SVCs
  - All SVCs are studied for spares. This include Booster, SVC2, SVC3, LHC Point 2,4,6, and 8 (SVC1 excluded)
  - Common spare coil (multi-tap) specification will be developed
  - Market survey for the coils complete
  - There’s enough spare thyristors for SVC2 and SVC3
- A universal spare thyristor fitting Booster and LHC SVCs
  - These are odd-type, 56 mm devices, 3 different “bands” available from a single source only
  - Availability ended this month, but order has been placed
  - Fits all locations
  - Enough 20 years operation

Harmonic Filters

- Simulation studies are required to confirm harmonic filter elements (coils and capacitor banks) loading
- A final count for spare capacitor and multi-tap coils:
  - 10% spares for ≤75% loading rounded up
  - 20% spares for ≥75% loading rounded up

ENS system

- The core of the Electrical Network Supervisor system consists of 2 HP-UX servers in redundant/hot stand-by configuration.
  - In case of SW failure a 24h/7d helpline with Efacec is in place
- Spare parts for other ENS components, such as RTU, DAU cards are kept in Prevessin
- Possibility of a CERN wide Schneider PLC spare parts management in 2008 (AB-CO)

48V-UPS Spares (LHC)

- All 48 V DC power systems run in parallel redundant configuration (n+1)
- Hot stand-by UPS systems required for LHC
  - Keeps batteries charged
  - Minimizes downtime (within contractual reaction time)
  - Hot spare center is foreseen

Stores/stock management

Stock of spares at present

- The stock is composed of :
  - Many individual pieces which reflect the condition of the installations:
    - large variety and frequently very old
  - Many components cannot be found anymore form the market
  - Many components are recuperated when renewing of installations
    - Difficult to follow an anticipated strategy
  - Stock is done as mounted units or sub-units, also as individual pieces
  - For major components, there is no spare strategy (see following slides)

- Management
  - Inventory is not organized on informatics support/applications (paper lists)
  - No computerized management of stores
  - Storage areas distributed all around CERN, no central stores for the group
  - Bdg. 226 is allocated for the store function
    - No manpower available to be devoted to this activity
  - Done in spare time by overloaded staff

How would we like to do things in EL?

- Prepare the inventory
  - Define strategic pieces (at least the minimum we need!)
  - Get rid of the obsolete components
- Produce a model for the data in D7i-stores module
- Coding, following the CERN precluded method
- Classification of pieces
  - Attributes
  - Generation
- Structuring and configuring
  - Which piece for which equipment
  - Versatility of pieces
- Start the real management of the stores
  - Definition of minimum levels
  - Management of costs
  - etc

Implementation of this cannot start before 2010 due to lack of resources

SPS Cables: strategy

- Replacing all cables is too costly (15 MCHF)
  - Consolidation includes BA6-BA7 plus one additional equivalent length (total of 2 MCHF)
- We have to get re-powering redundancy everywhere => consolidation for BA4 urgent, foreseen end of 2008

- TTR a faulty cable varies from 1 week to 1 month
  - Many variability factors (location, weather, access rights to locations,…)
  - In the meantime, operation in open loop configuration
  - Double faults kill this possibility, low probability which will increase with time…
- 30% of the cables have been replaced in SPS loops, none for the SMB cables
- BA6-BA7 can be used as a “pilot programme” for the future procedure
  - Cables will be laid within PVC pipes
- A new procedure “Guide pour la réparation des cables du SPS” has been prepared, will soon be published

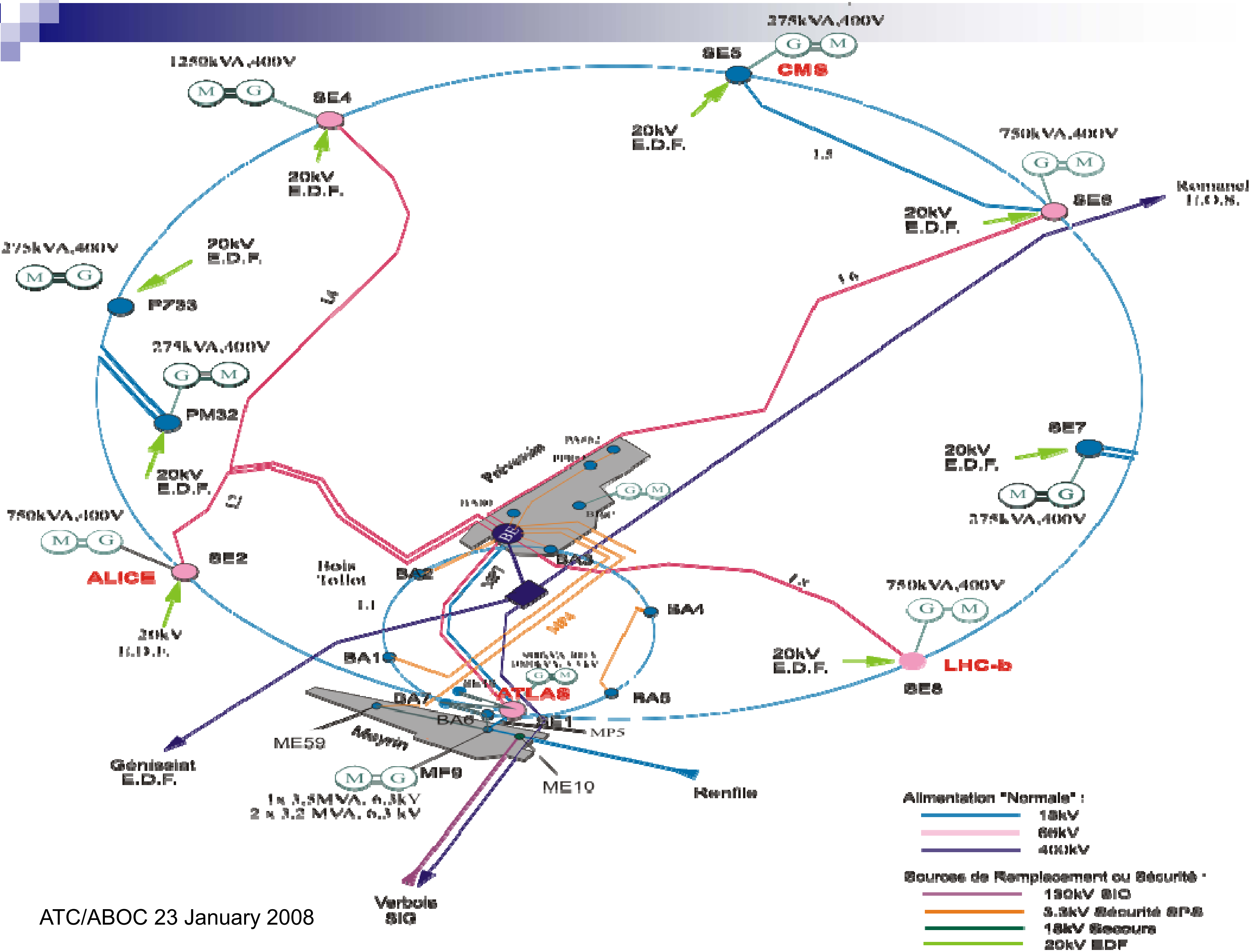
Conclusions

- Critical zones with no redundancy have to be consolidated
  - BA4 is programmed for next shutdown
- Maintenance contracts
  - Reactivity to be further studied and included contractually
  - Missing contracts to be prepared
- Minimum list of spares to be defined
  - Budget impact
- Stock management
  - Manpower + budget impact
- SPS Cables
  - Strategy for 18 kV cables defined
- Documentation
  - well established and organized procedures are required
  - feedback from the field

Spare slides

Electrical Power Distribution @ CERN

- Meyrin site
  - Regular network: supply of all loads (PS, Booster, Linac, AD and General Services)
  - Safety network: supply of personnel safety equipment in Meyrin site (Meyrin diesel generators)
- SPS & North Area
  - Pulsed network: supply of accelerator loads (18kV closed loop)
  - Stable Services: supply of general infrastructures (18kV closed loop)
  - Safety network: supply of lifts (from Meyrin diesel generators)
- LHC
  - Machine network: supply of accelerator loads
  - General Services: supply of general infrastructures (18kV closed loop)
  - Safety network: supply of personnel safety equipment (LV generators)



275kVA,400V
SE5
CMS
1250kVA,400V
SE4
20kV
E.D.F.
750kVA,400V
SE6
Romanel
E.O.S.
275kVA,400V
P733
PM32
SE7
375kVA,400V
750kVA,400V
SE2
ALICE
Bois Tollot
BA2
BA3
BA4
BA1
BA5
BA7
BA6
ATLAS
SE1
MP5
LHC-b
SE8
ME59
Meyrin
MF9
1x 3,5MVA, 6,3kV
2 x 3,2 MVA, 6,3 kV
ME10
Renfile
Génissiat
E.D.F.
Verbois
SIG
Alimentation "Normale" :
18kV
66kV
400kV
Sources de Remplacement ou Sécurité :
130kV SIG
3.3kV Sécurité SPS
18kV Secours
20kV EDF

Electrical Equipment Spares at Fermilab

- Three categories
  - High voltage equipment spares
  - Common electrical parts
  - Safety related
- Two locations
  - Common parts and safety equipment stockroom
  - Special spares warehouse

Electrical Equipment Spares at Fermilab

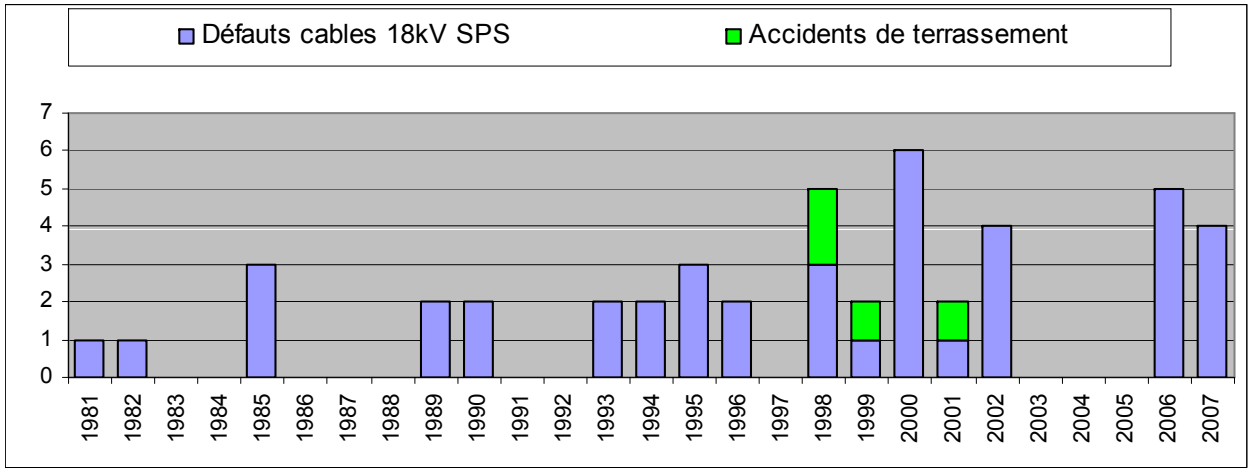
- All high voltage equipment is bar-coded. Information include:
  - Location of spares
  - Responsible engineer
  - Reviewed yearly by a responsible engineer
- All common equipment is stocked
  - Common equipment definition
  - Restocked if needed
  - Reviewed yearly by the electrical stockroom supervisor

Electrical Equipment Spares at Fermilab

- Both locations manned by 3 full-time employees, day shift, available on-call after-hours
- Safety equipment and a selection of common equipment are also stocked locally (pre-defined quantities) in electrical maintenance department
- Re-stocking automatic

SPS Cables: strategy

- Replacing all cables is too costly
  - Consolidation includes BA6-BA7 plus one additional equivalent length
- We have to get re-powering redundancy everywhere (not the case in BA4) => consolidation



Situation actuelle
Câbles remplacés ou neufs

- Étude complète des boucles stables et pulsée réalisée

- Boucle stable tronçons remplacés à ce jour (33%)
  - tronçon BE-BA2 en service (2001)
  - tronçon BE-BA3-BA4 en service (2003)
  - tronçon BA4-BA5 (2004) tiré en attente raccordement

- Boucle pulsée remplacés à ce jour (25%)
  - tronçon BE-BA3-BA4 en service(2003)
  - tronçon BE-BA4 en service(2003)
  - tronçon BA4-BA5 (2004) tiré en attente raccordement

- Alimentation BE-TI8 en service (2003)

C. Gascon ATC, Oct 26 2006