CERN Electrical Infrastructure

Canadian Light Source visit to CERN for Infrastructure matters, 6-7 June 2019

Davide Bozzini, CERN Electrical Group

CERN | EN ENGINEERING DEPARTMENT

Agenda

1. The CERN electrical group
2. The CERN electrical network
3. Network supervision
4. Network operation
5. Integration studies
6. Examples
7. Ongoing and future projects

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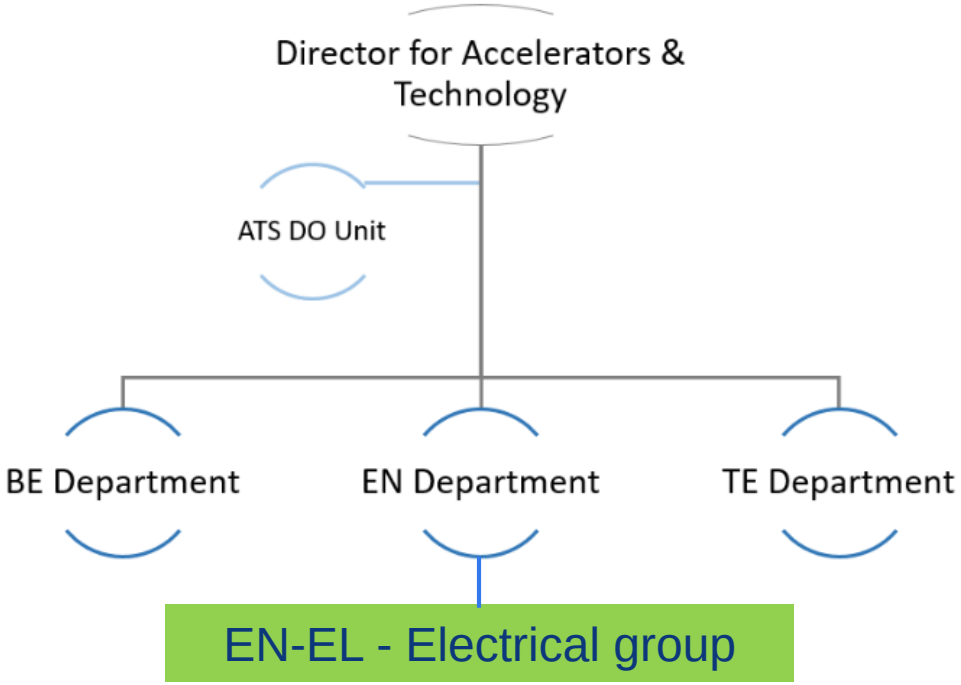
Accelerators & Technology Sector



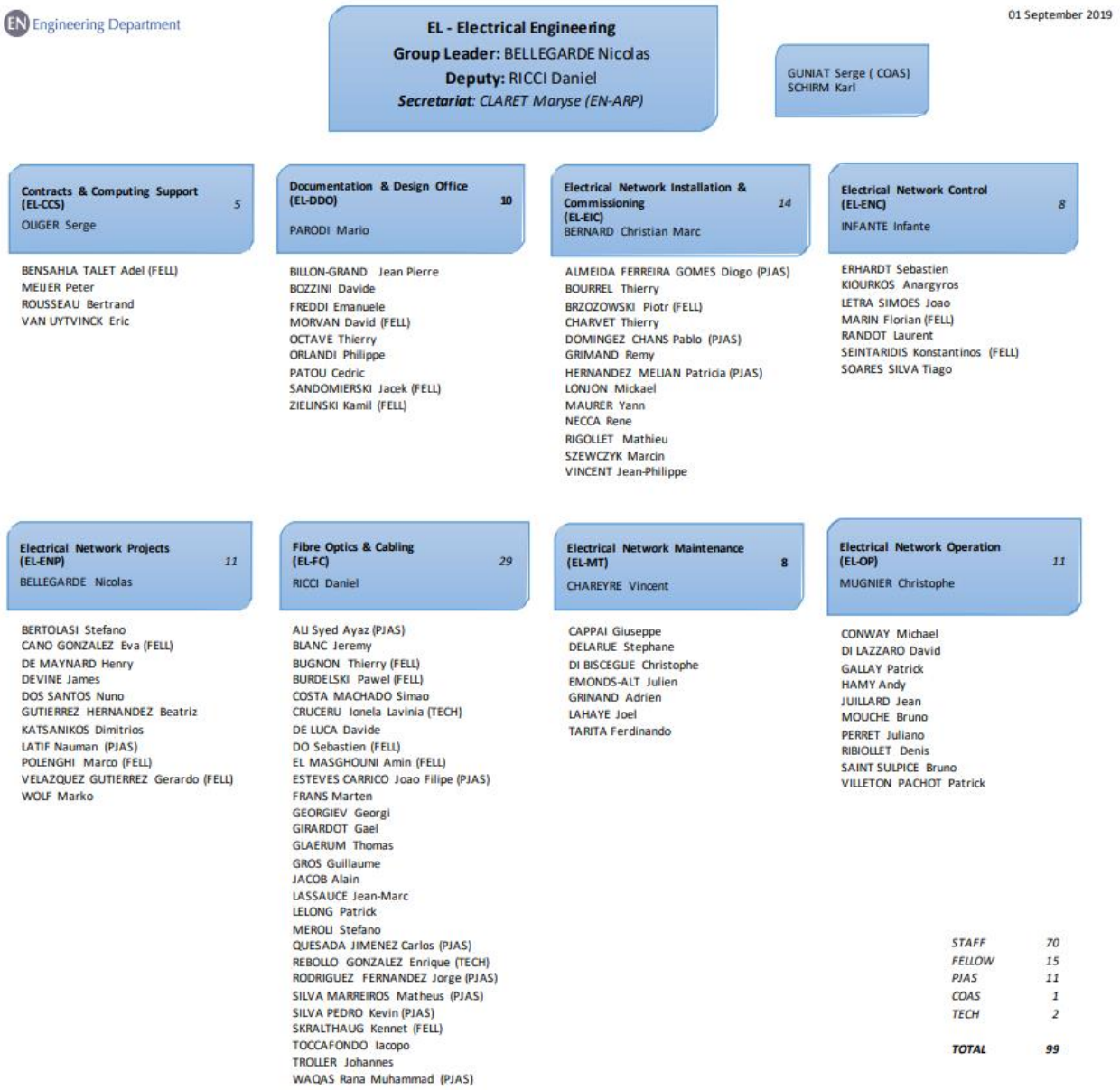
The ATS-Directorate Office (ATS-DO) is a unit of the Accelerator and Technology sector staffed by persons working on projects or studies such as HL-LHC, FCC, CLIC and EU activities.

The Beams Department hosts the Groups responsible for the beam generation, acceleration, diagnostics, controls and performance optimization for the whole CERN accelerator complex.

The Engineering Department provides CERN with the Engineering Competences, Infrastructure Systems and Technical Coordination required for the design, installation, operation, maintenance and dismantling phases of the CERN accelerator complex and its experimental facilities.

The Technology Department is responsible for technologies which are specific to existing particle accelerators, facilities and future projects. These include magnets, their machine integration and protection, power converters, cryogenics, high and ultra-high vacuum systems, coatings and surface treatments.

Group structure



Personnel statistics on 1st February 2019

	EN-EL	CCS	DDO	EIC	ENC	ENP	FC	MT	OP	TOTAL
STAFF	2	4	7	10	6	6	16	8	11	**70**
FELLOW		1	3	1	2	3	4			**14**
PJAS				3		1	7			**11**
COAS	1									**1**
TECH							1			**1**
TRAINEE										**0**
TOTAL	**3**	**5**	**10**	**14**	**8**	**10**	**28**	**8**	**11**	**97**
DETACHES (STAFF)	1									**1**
ENTC			4	1	2		2		2	**11**
FSU				7			1	1		**9**
TEMC							1			**1**

GRAND TOTAL	119

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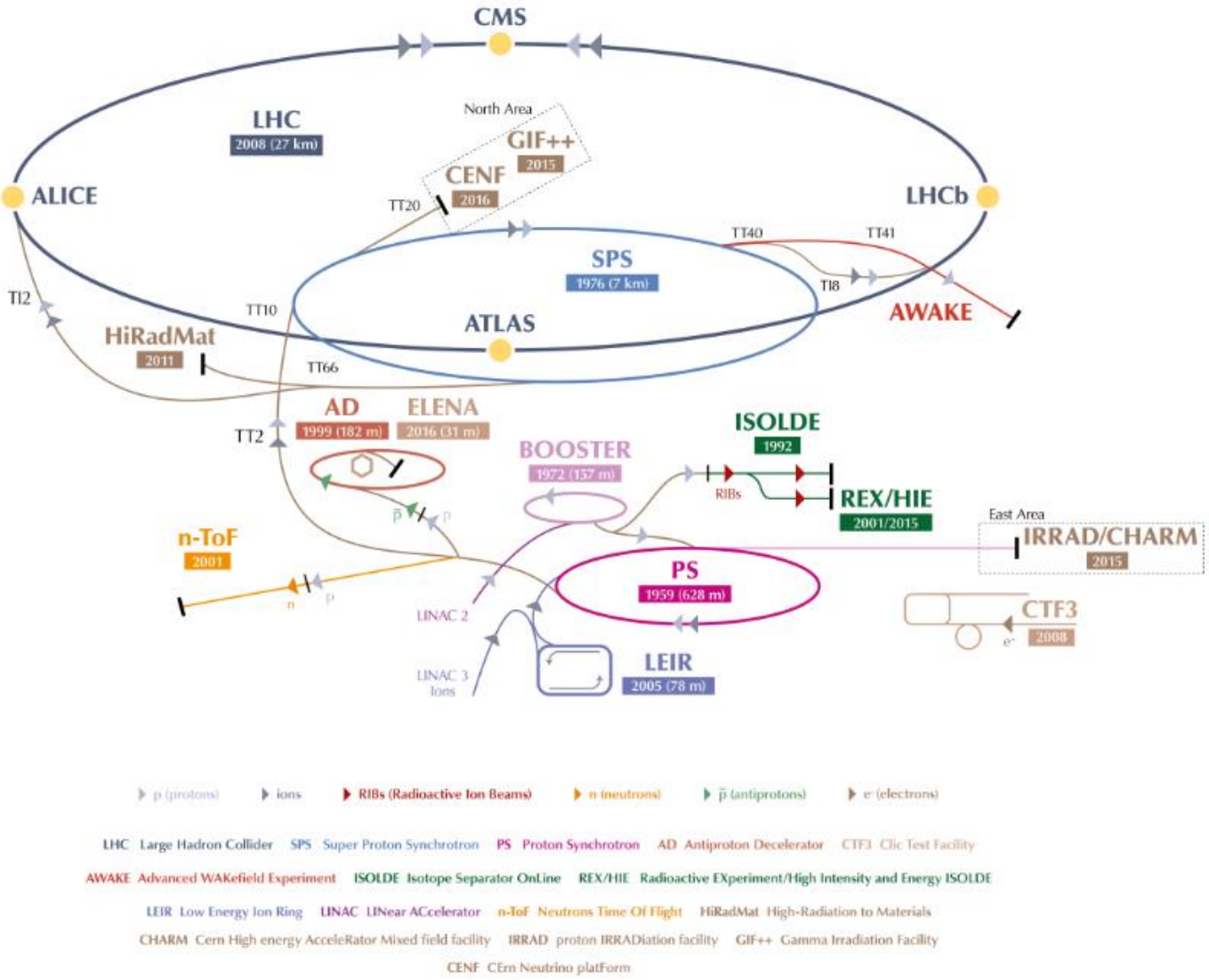
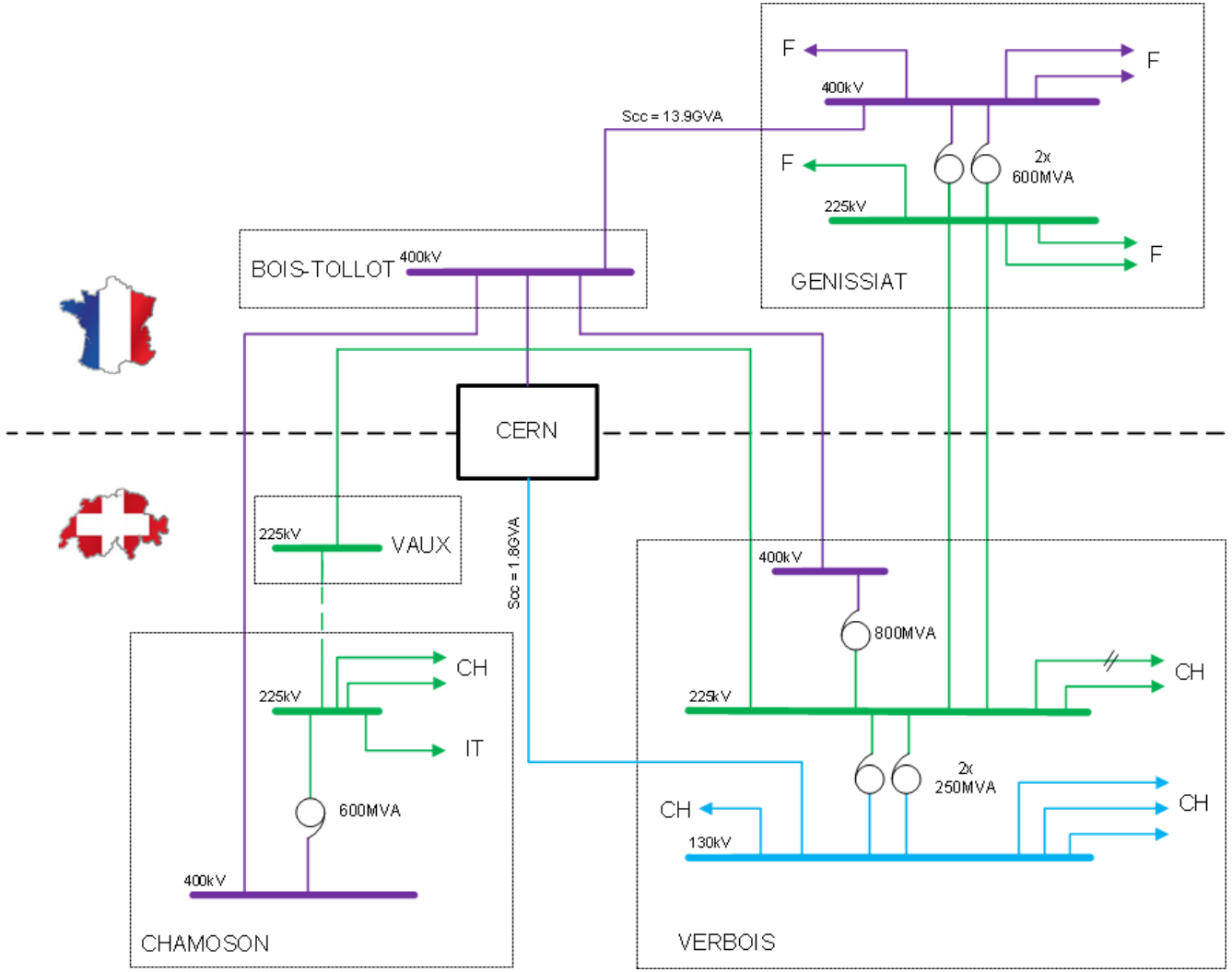
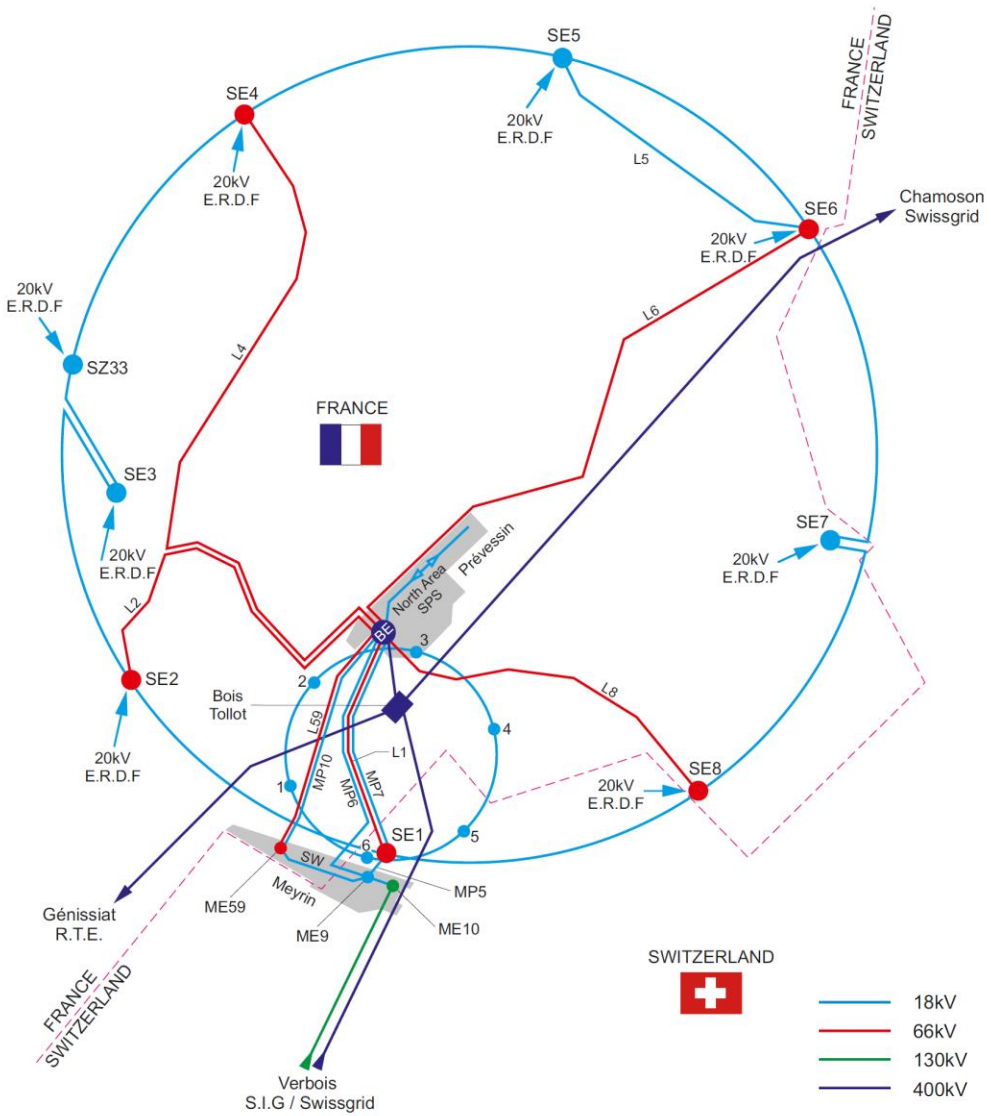
CERN accelerators complex

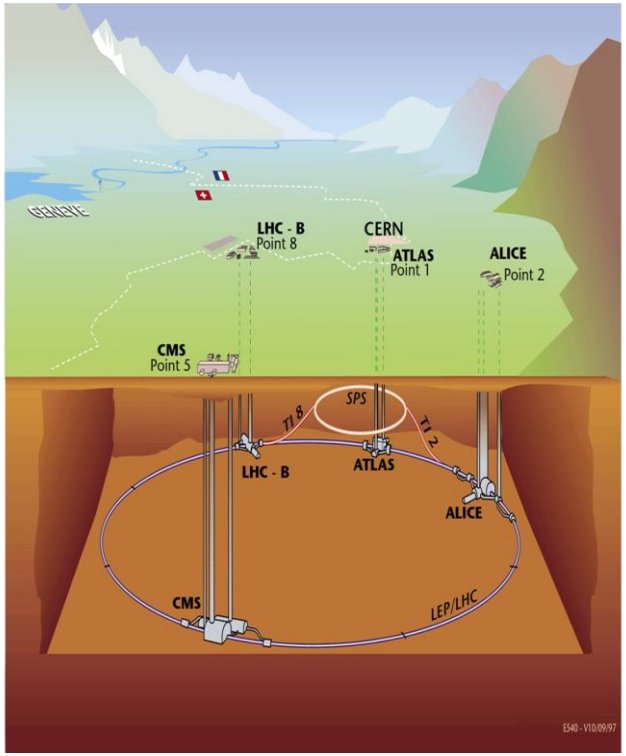


The Sources of Energy at CERN



Electrical network: geographical extension





Voltage levels:

- 400 kV main incomer
- 66 kV transmission
- 18 kV distribution
- 3.3 kV motors
- 0.4 kV users

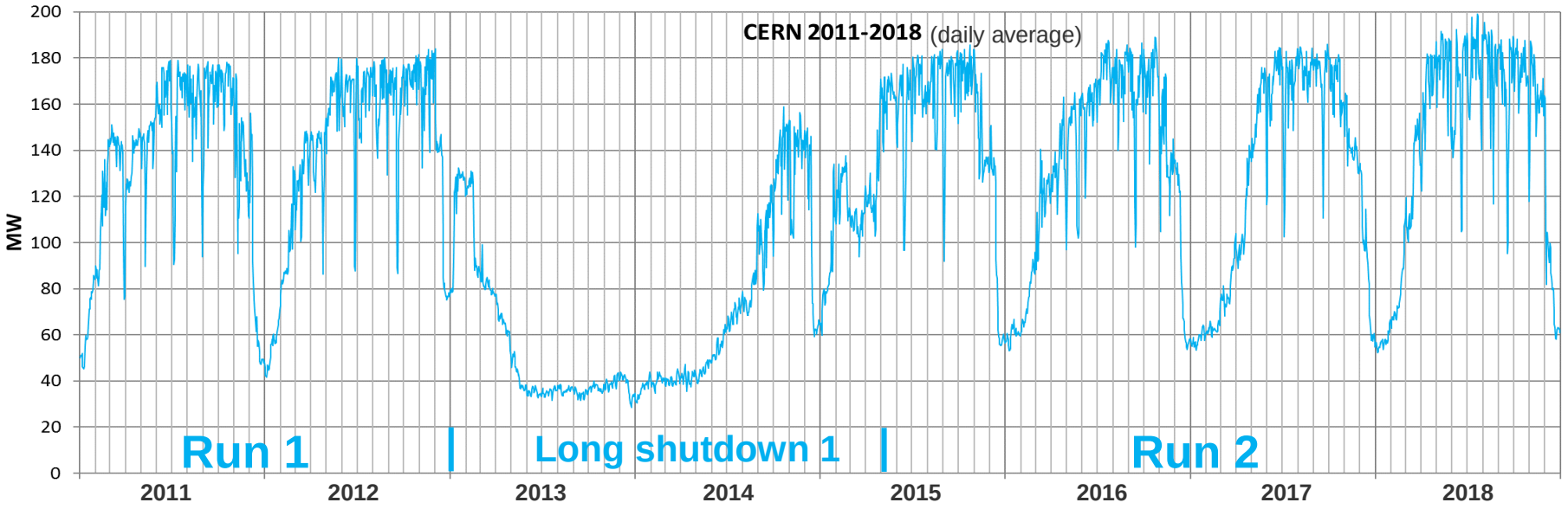
Electrical consumption: typical figure

GWh (annual consumption)

- 1’200 GWh (normal operation year)
- 350 GWh (shutdown year)

MW (max active power)

- 190 MW (daily average)
- 210 MW (10-min average)
- 320 MW (instantaneous)



Courtesy B. Mouche / EN-EL

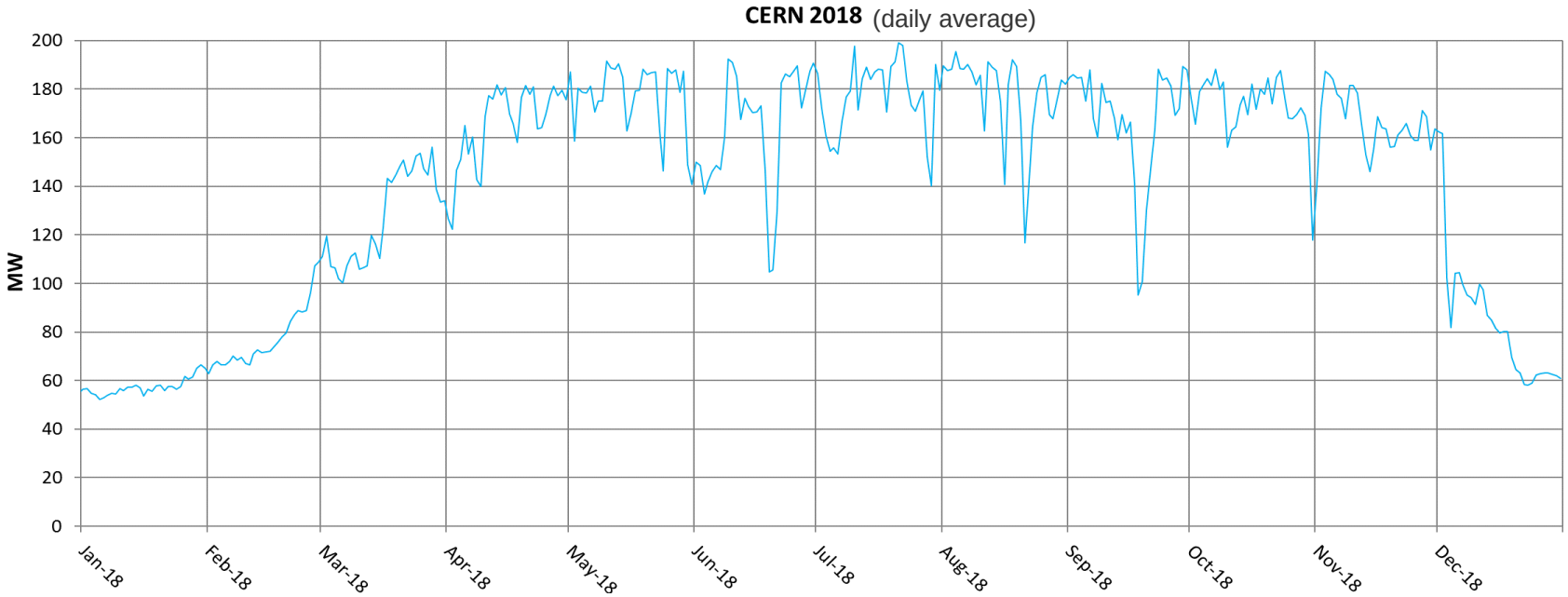
Electrical consumption: 2018 figures

GWh

- 1’251 GWh

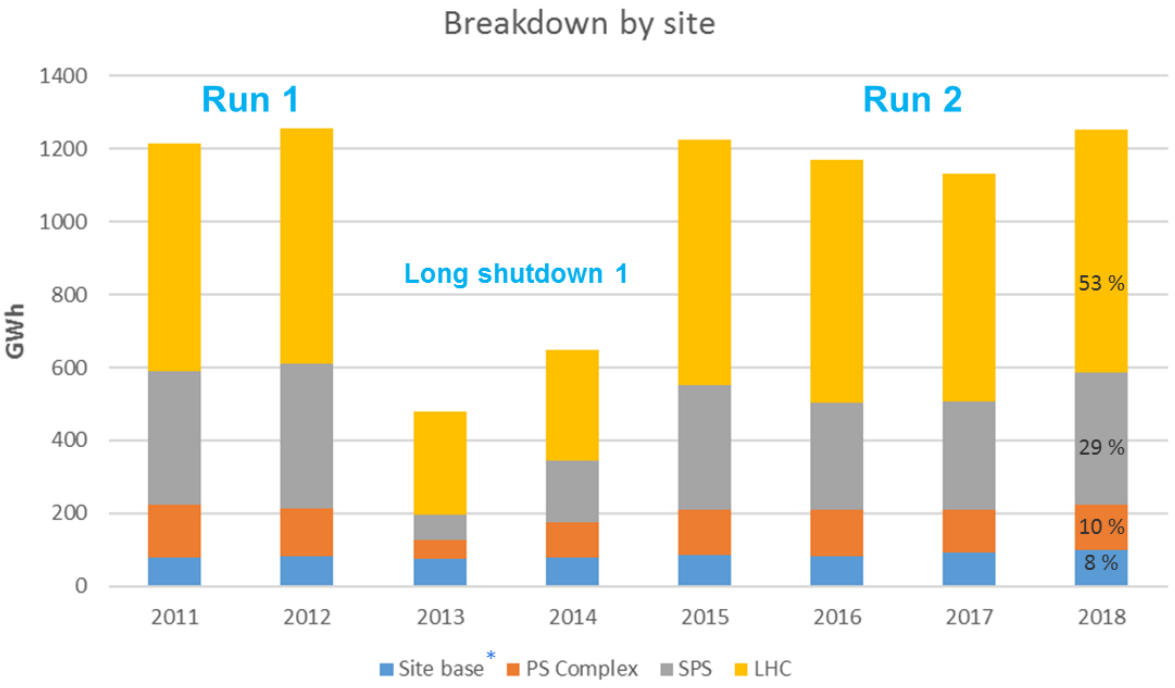
MW

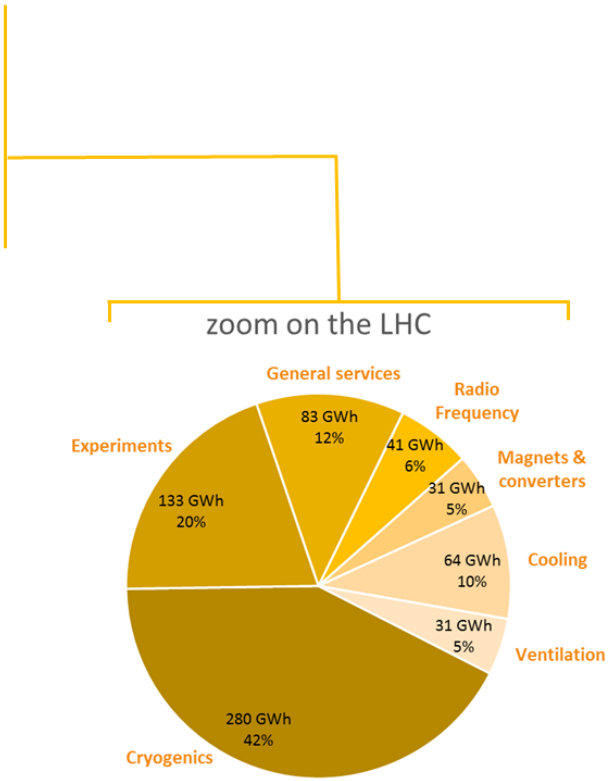
- 199 MW (daily average)
- 215 MW (10-min average)
- 320 MW (instantaneous)



Courtesy B. Mouche / EN-EL

Electrical consumption: Zoom on LHC





* Site base =
- office buildings (Meyrin & Prevessin sites)
- central services (computer center, pumping station)

Courtesy B. Mouche / EN-EL

“Components” of the network

Can be classified in 5 groups:

HIGH VOLTAGE

- Transformers
- MV Cables
- Switchgear
- Gensets

LOW VOLTAGE

- 48 V_{DC} systems
- UPS
- Switchgear and switchboards
- LV Cables
- Gensets

CONTROL

- SCADA
- RTUs

CABLING

- Signal cables
- Coaxial cables
- Water cooled cables
- Optical fibers
- Connectors

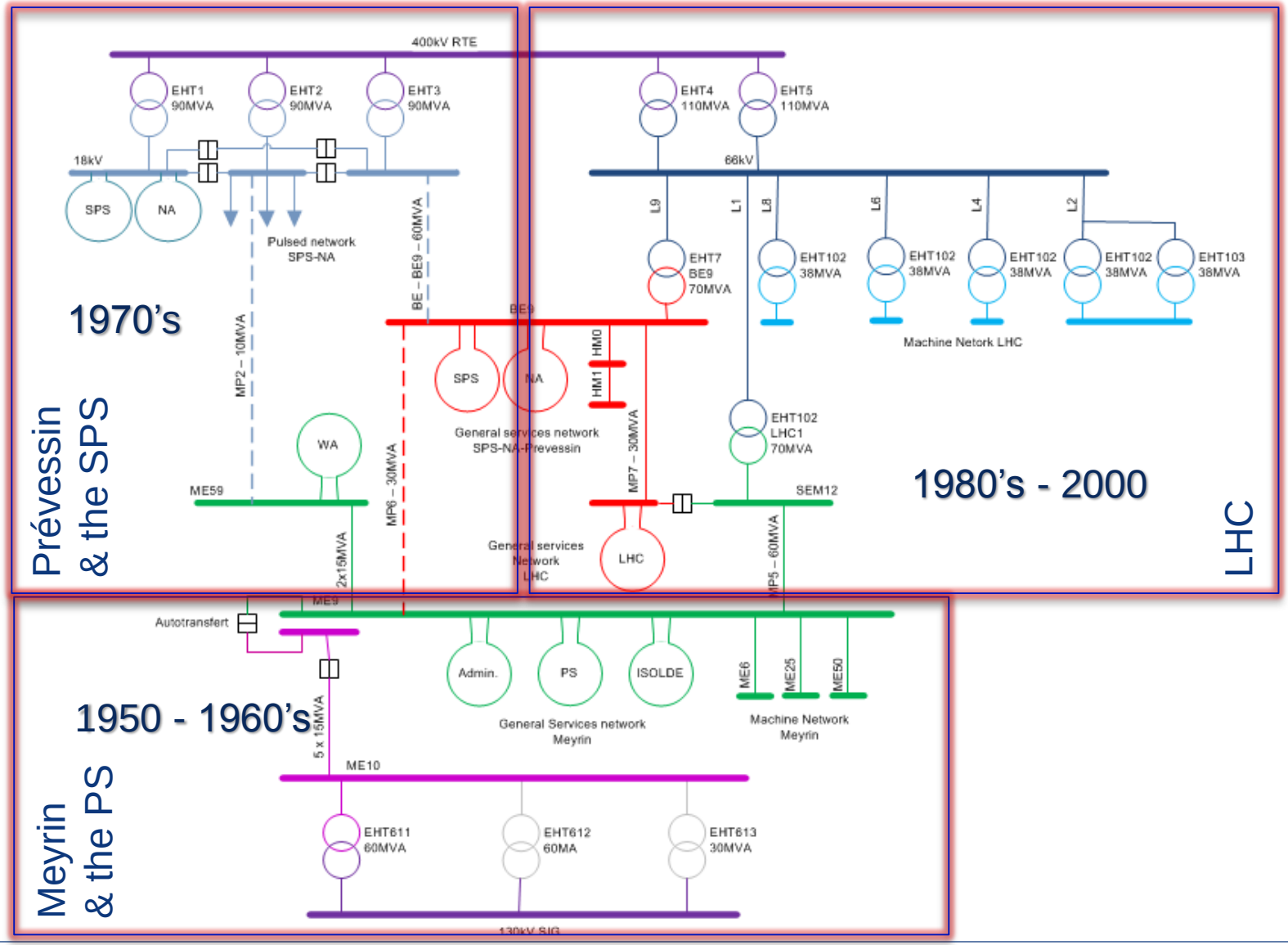
ENERGY

- Supply of energy

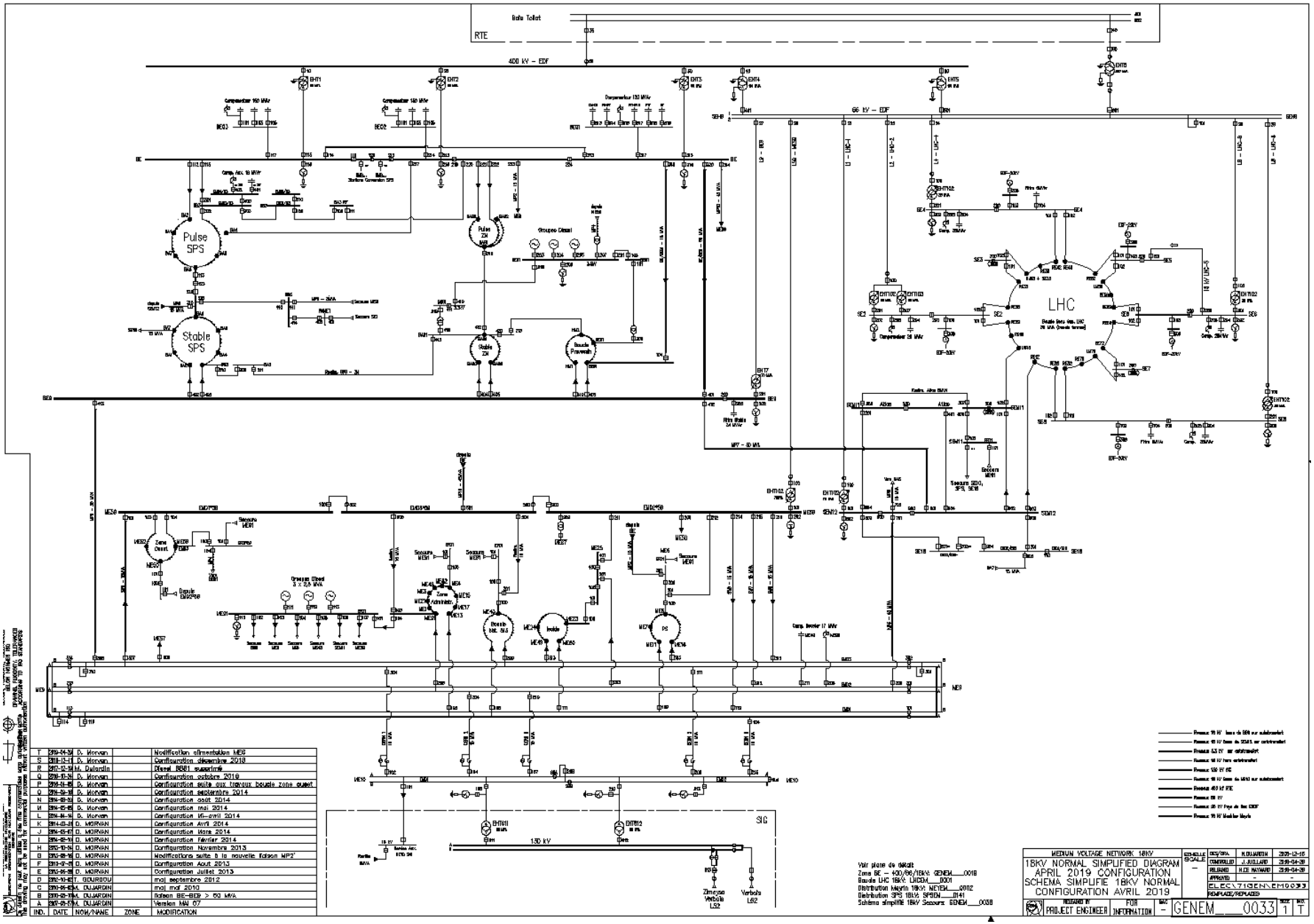
Type and quantity of equipment

Equipment type	Quantity
Power transformers (400 kV and 66 kV)	6 + 8 (Installed power 710 + 400 MVA)
Distribution transformers (18/0.4 kV)	~750 (oil and dry-type)
High voltage switchgears (18 kV & 3.3 kV)	~1 000
Low voltage feeders	~30 000
UPS	~300
48 Vdc battery systems	~100
Network protection relays	~1 000
Gensets	17 (Installed power 22 MVA)
Water cooled cables	1 500 (length 3 to 250 m)
SCADA	23 000 devices / 250 000 data-points

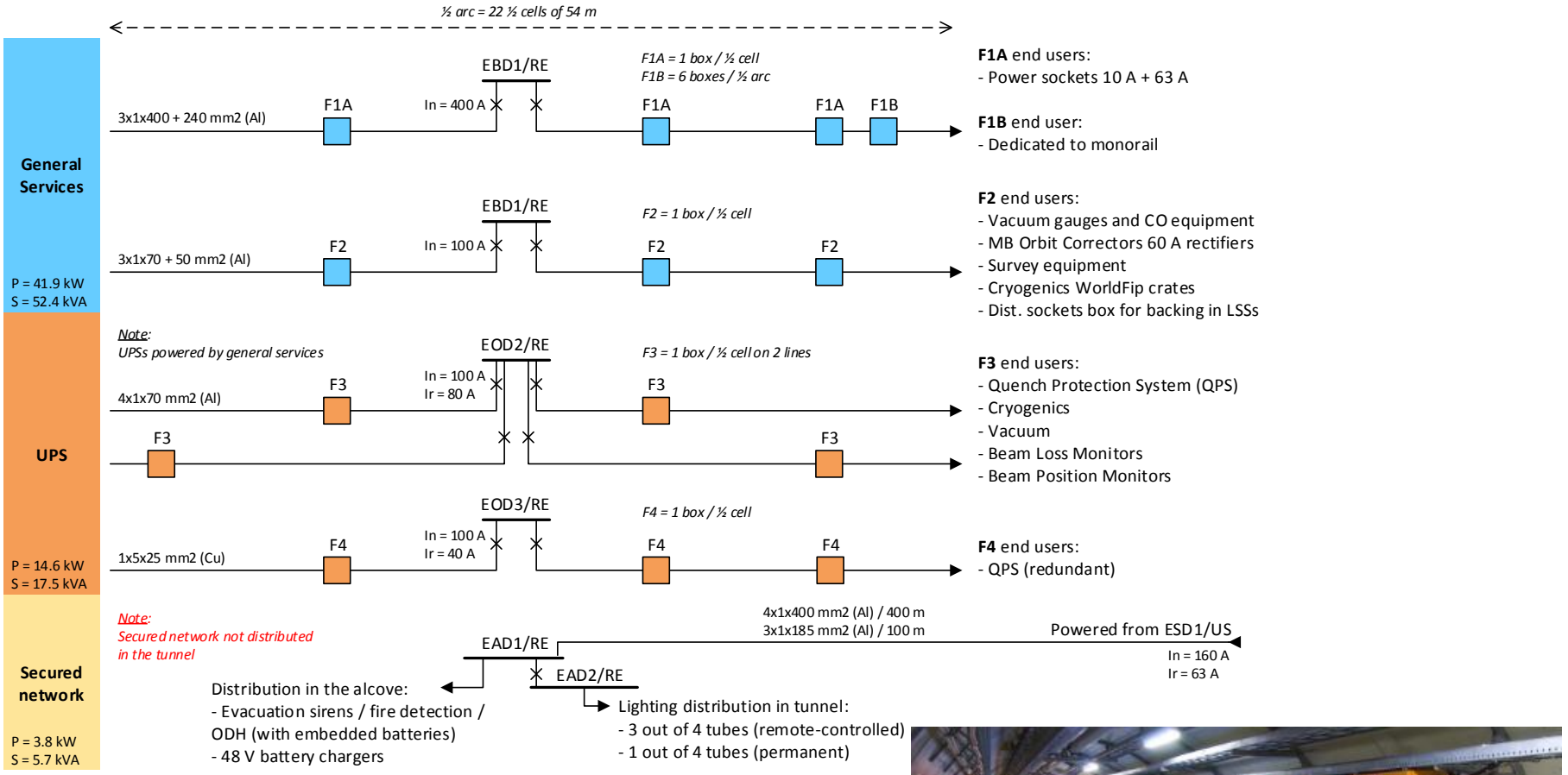
Evolution of the HV Network



Simplified single line diagram



Distribution in underground (LHC Tunnel)



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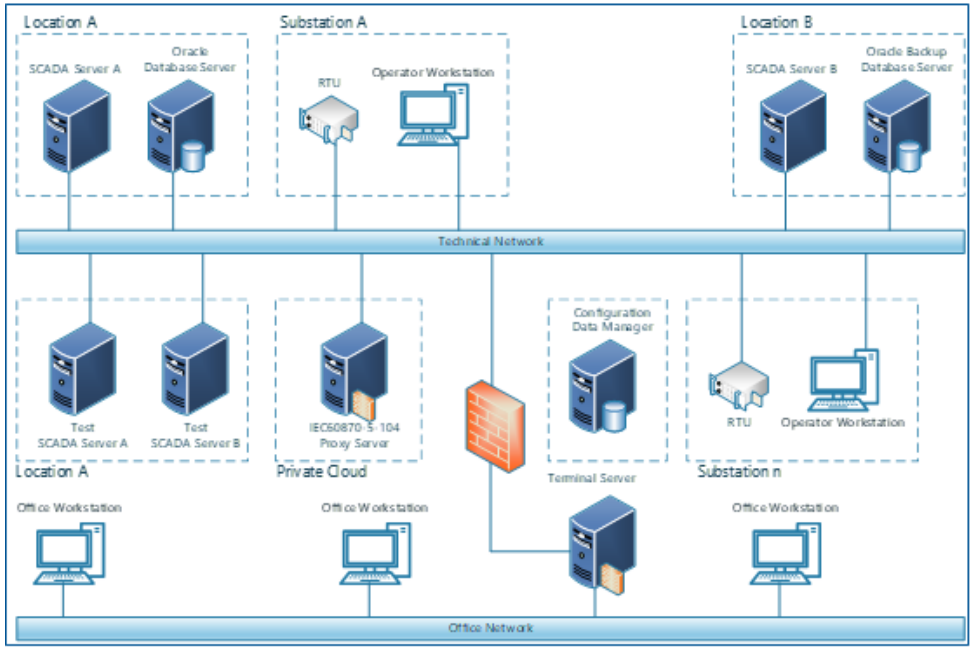
CERN ELECTRICAL NETWORK SUPERVISION System

The ENS is the supervision system of CERN electrical network.

It provides, to the CERN Control Centre (**CCC**) and the electrical operators, remote monitoring and control of the majority of electrical equipment installed in surface, underground and experimental areas, from 48Vdc battery charger systems to 400kV circuit breakers and transformers, to Diesel Generators, UPS and high voltage protection relay systems.

Over 23,000 devices, with approximately 280,000 data-points, are connected through serial buses, Ethernet networks and various communication protocols, to 70 Remote Terminal Units (**RTU**) installed in the main electrical substations.

A redundant and central **SCADA** system, collecting data from the 70 RTUs, provides to the operators a Graphical User Interface (**GUI**) with synoptic panels, alarms and events related to the electrical network.



ENS Architecture

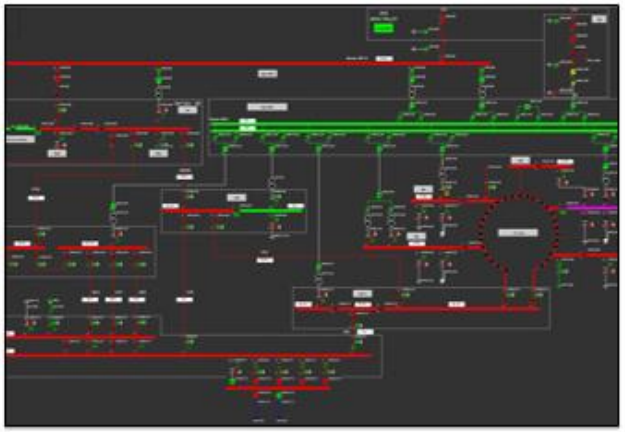
300 **remote I/O** stations are installed in electrical substations collecting digital input and output signals (status, alarms, open/close commands…) from electrical equipment.

Several **PLC** systems are installed in important substations for automatic network switch-overs and start of Diesel Groups in order to resupply critical loads in case of loss of the main power source.

High voltage circuit breakers are interfaced with protection relay systems, designed to trip the breakers when a fault is detected. The newer generation of protection relays, also called **IED**s, are microprocessor based digital devices and use the substation communication network for protection and data collection.

Courtesy S. Infante / EN-EL

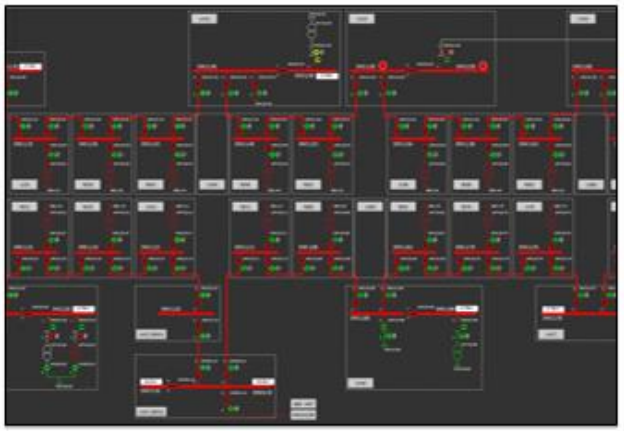
CERN ELECTRICAL NETWORK SUPERVISION System



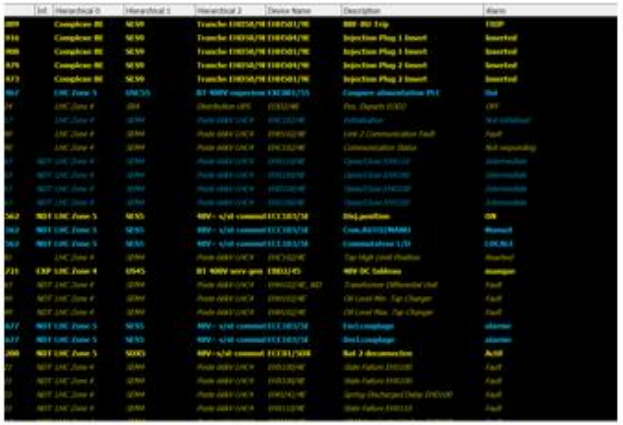
Single Line Diagram representing the transport network powering the entire CERN

The SCADA synoptic panels display the live status of the electrical network, through dynamically coloured lines, representing electrical single line diagrams.

The red colour represents an energised line (presence of voltage). The green colour represents a non-energized line (absence of voltage).



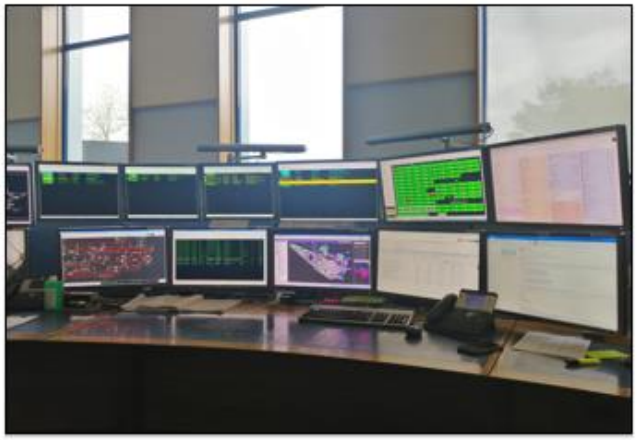
Single Line Diagram representing the 18kV network powering the LHC



SCADA Alarm list

The SCADA Alarm list reports in real time alarms related to the electrical network or to the ENS system.

The different colours of alarm lines visually alert the operator of the severity of the alarms. In case of high priority alarms, the CCC operator will call the electrical or control expert in stand-by at any time.



CCC – CERN Control Centre – TI post

Courtesy S. Infante / EN-EL

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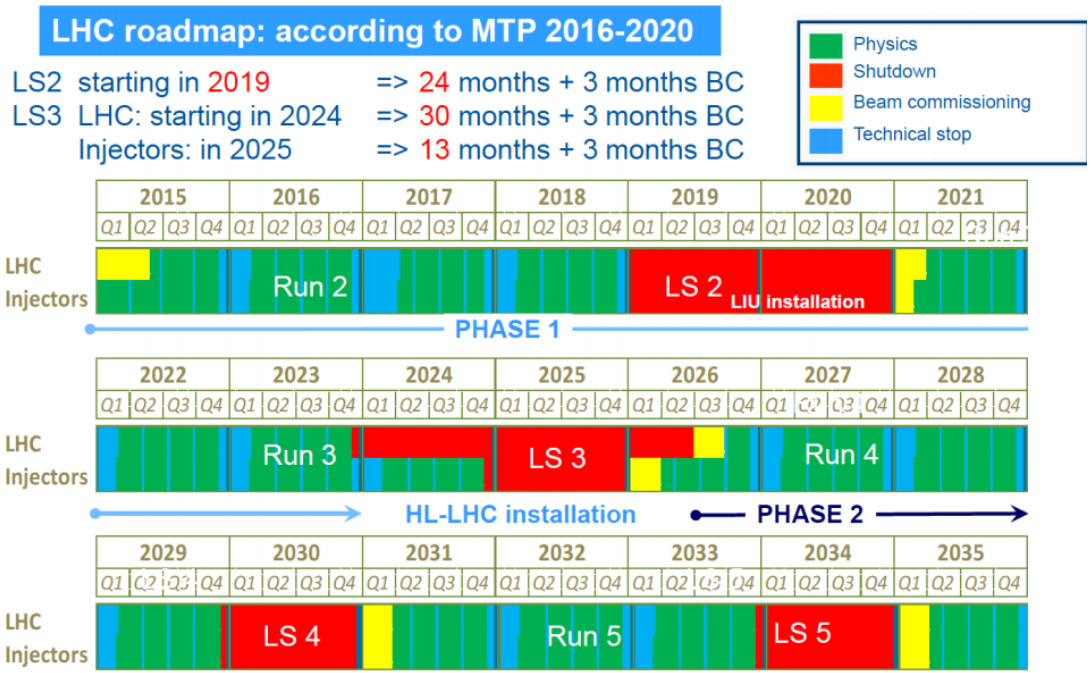
Network operation schedule

Maintenance and consolidation of electrical infrastructure is driven by the LHC roadmap

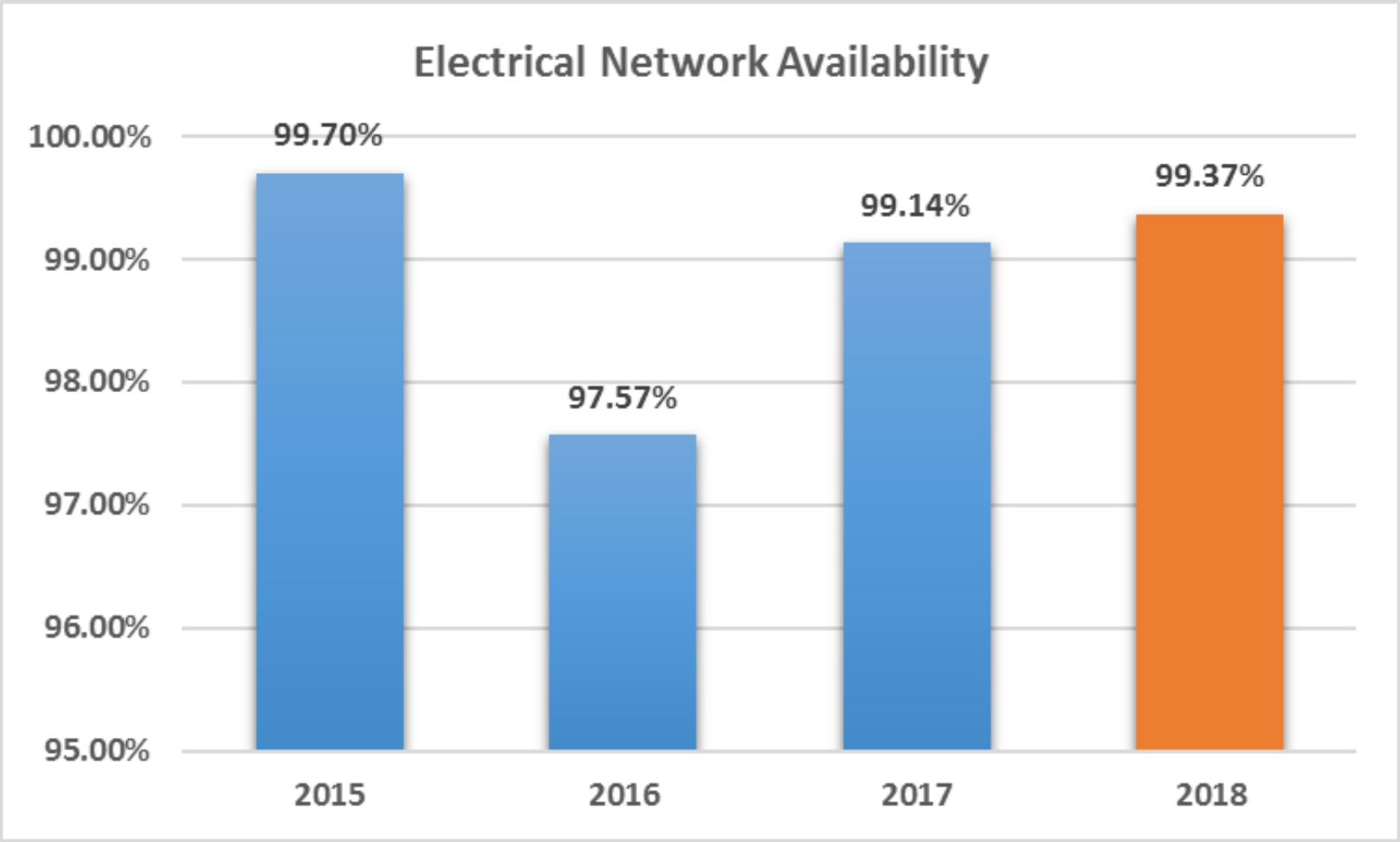
Typically **3 years physics** run followed by a **2 years long shutdown**

End of the year stop of **2-3 months**

3 short technical stops **(3-5 days)** every year



EN-EL's operational performance



- Note: external electrical perturbations excluded

Operation and maintenance in 2018

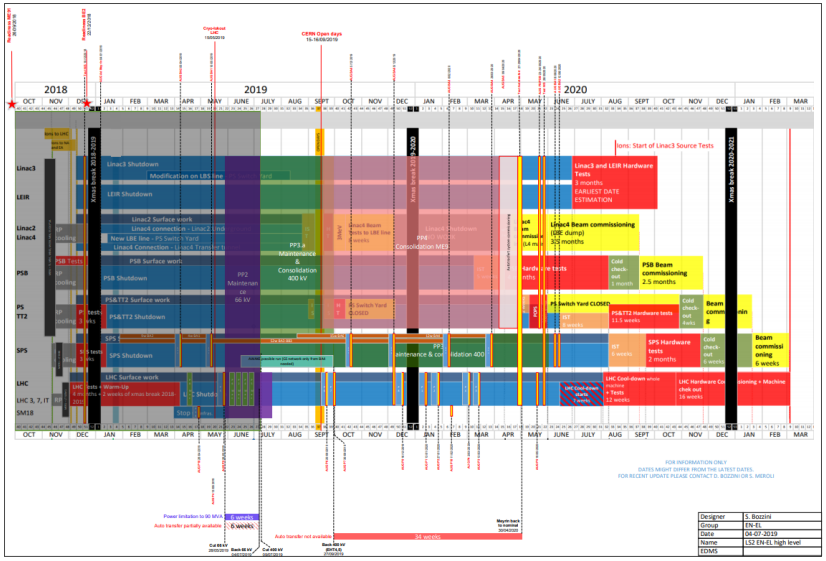
- Key figures for a year of physics run
  - 50+ “notes de coupure”
  - 800+ energizations and electrical lock-outs
  - 100+ interventions from the stand-by team
  - 50 Major Events, incl. 31 external perturbations

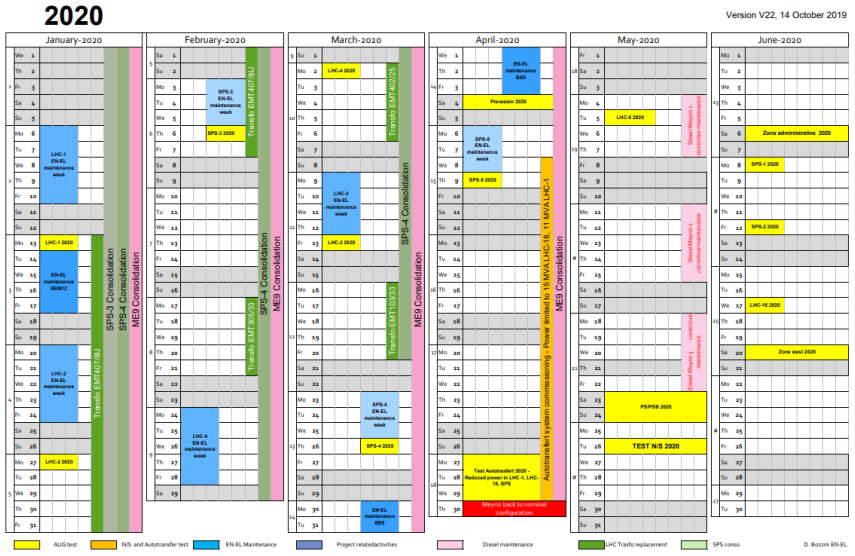
Activities coordination (Example of LS2)

Activities on accelerators infrastructure managed by a dedicated committee and coordinated by a dedicated team

Electrical group provides inputs and participate to the preparation of the baseline (typically 3 years before LS)

During execution period, weekly follow-up and detailed schedule





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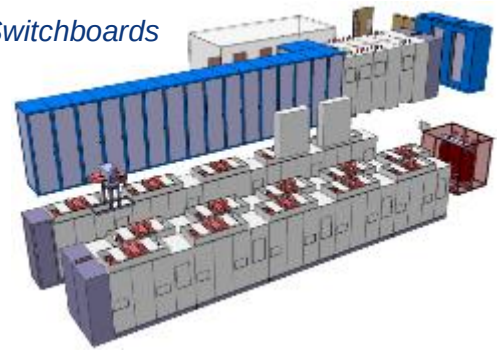
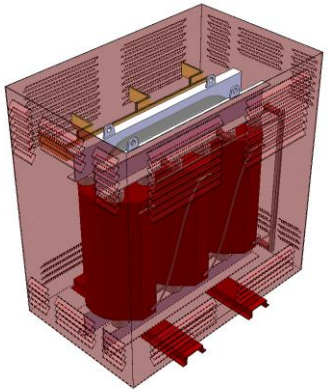
Integration studies

- 3D Integration:
  - Projects & substations
  - Integration studies of electrical equipment (racks) for all CERN users
  - Integration studies of cable trays for all CERN users
- 2D drawings for installation
- Building layouts

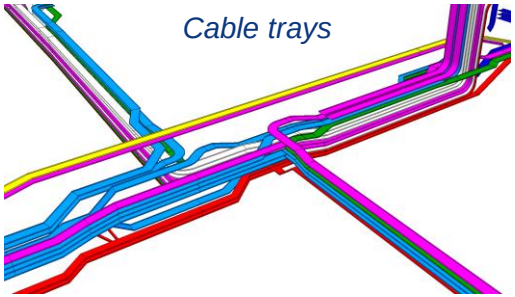
Switchboards



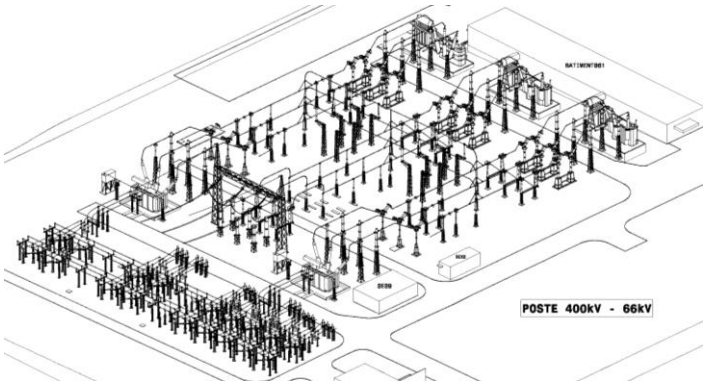
Transformers



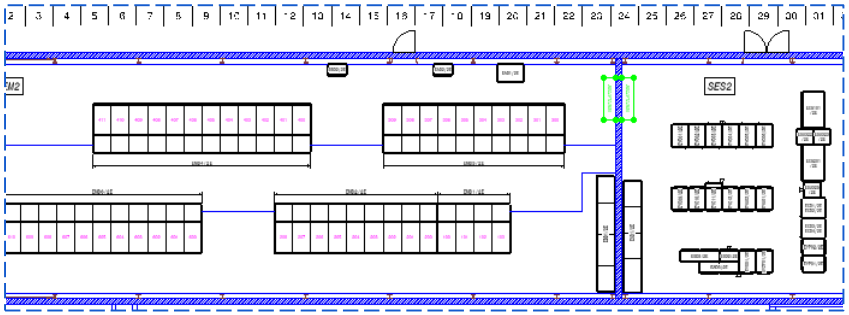
Cable trays



Substations



Layouts



Integration studies

EL Electrical group

2D (Layouts)

3D

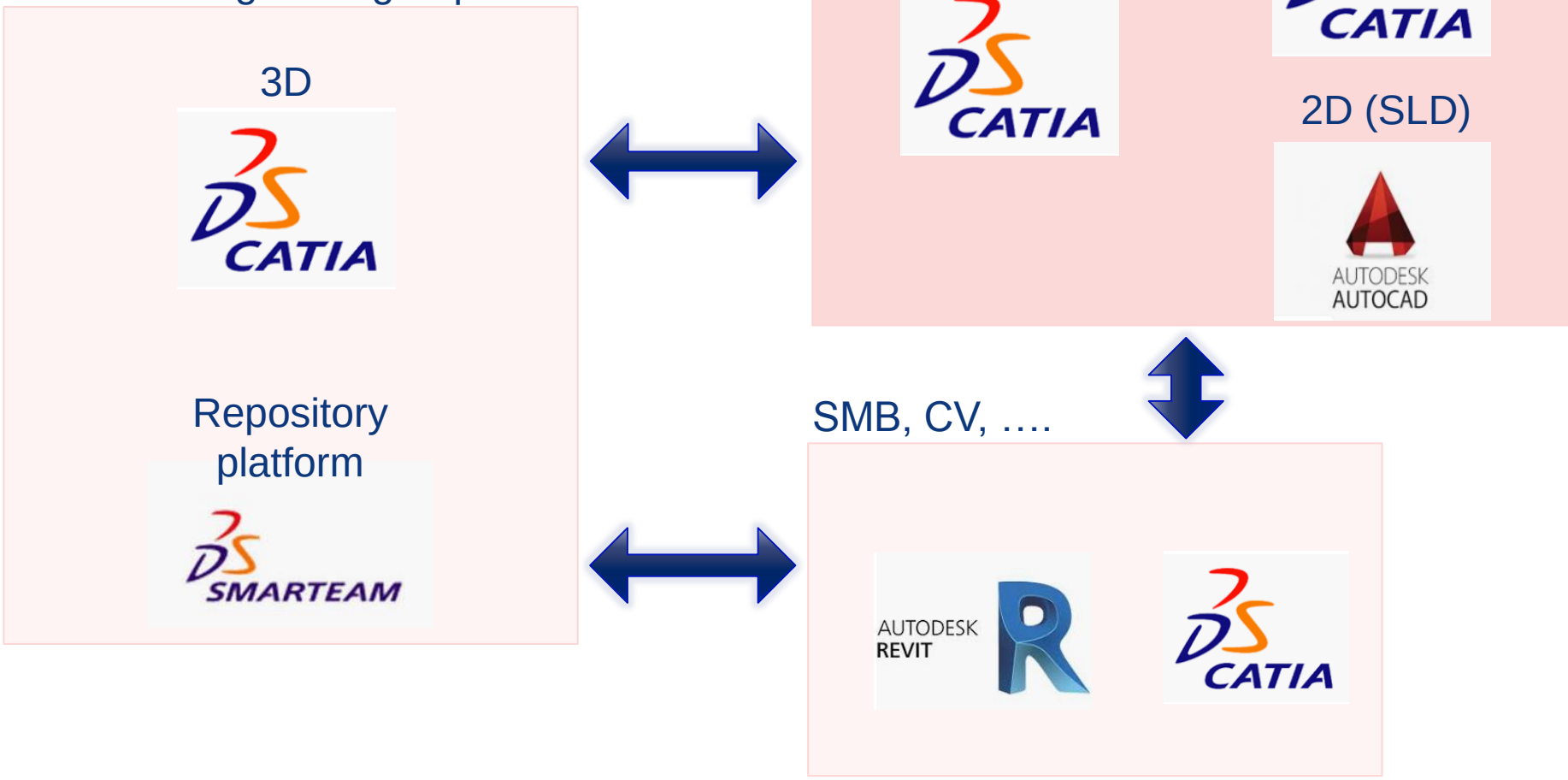
2D (SLD)

EN-ACE Integration group

3D

Repository platform

SMB, CV, ….



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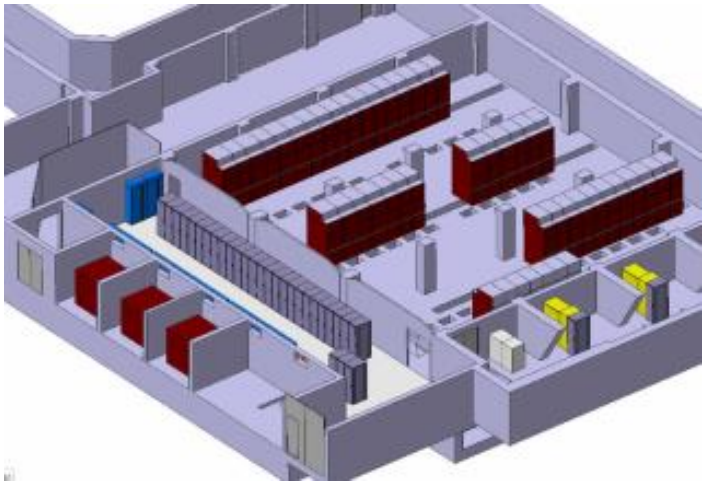
Example 1: Renovation of substations

- Integration by CERN,
- Equipment provided via blanket contracts
- Construction via existing service contracts

Example 2: Upgrade of substations

- Design and integration by EN-EL
- Equipment provided via blanket contracts
- Construction via existing service contracts



Example 3: New diesel power station

- Diesel generator power station for the Meyrin site with 3 x 2.5 MVA gensets
- Tunkey project

Example 4: Network protection systems

Consolidation of 400/66 kV substation in Prévessin

- Continuation of the works carried out during LS1
- New oil retention pits and *firewalls*
- Replacement of several electrical equipment

Management of new protection relays

- First IEC 61850 GOOSE-based substation in ME91 and SE18

Example 5: 400 kV transformer substation

- Construction of a new 400 kV substation with a 220 MVA power transformer
- Turne key project

Example 6: Fibre Optics and cabling

LS2 numbers	Fibre Optics	DC-power Cabling for accelerator magnets	Signal Cabling for CERN users	
No. of cables	1400	1200	11500 (new)	20000 (removal)
Length [km]	120	24	800	900

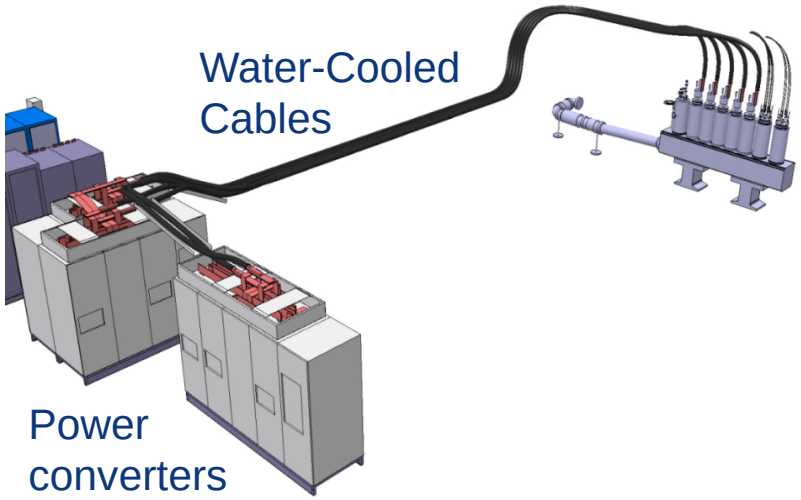
Example 7: Water-cooled cables

These flexible water-cooled cables or “WCC” are used for transporting high DC current from power converters to superconducting current leads.

DC current rating up to 15000 A

Activities

- New installations on test benches
- Maintenance activities on existing cables or replacement
- New cables design for HL-LHC
- R&D required



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Ongoing and future projects

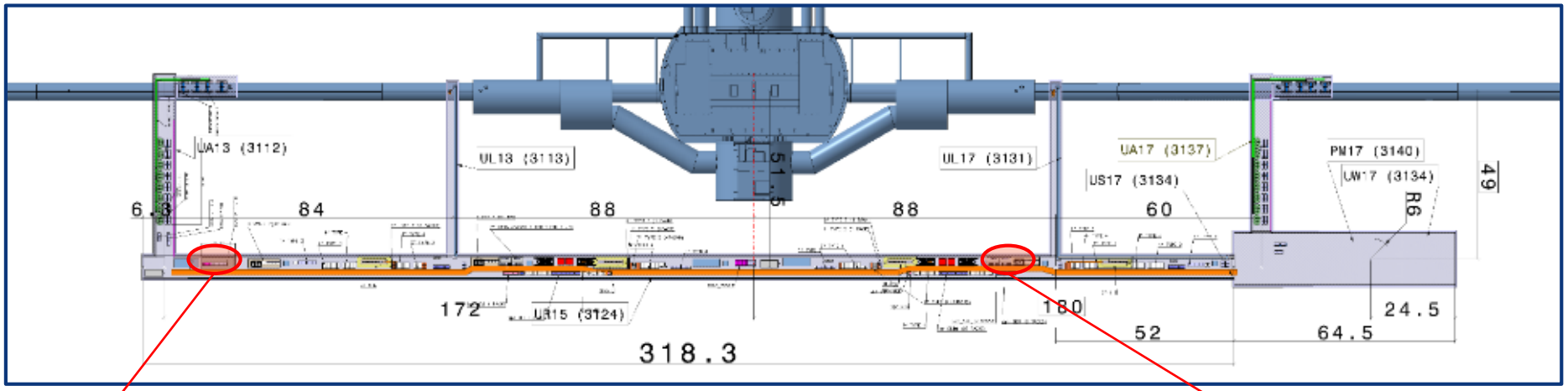
Mid -Long term (2020 to ……):

- Yearly consolidation and maintenance activities and approved projects design and execution

- HL-LHC, prject approved study phase of electrical infrastructure well advanced, some works already planned during LS2

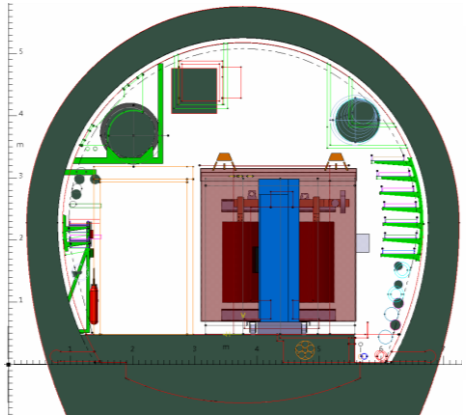
- According to the roadmap of the European Strategy for Particle Physics, CERN will hopefully host new accelerator infrastructures such as FCC, CLIC,….

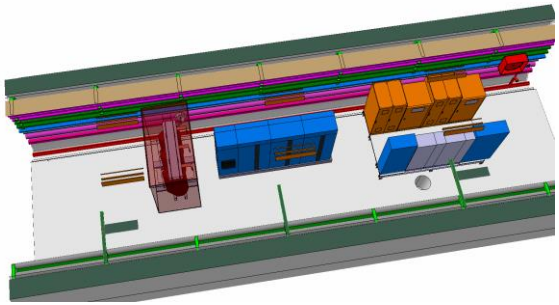
HL-LHC electrical infrastructure

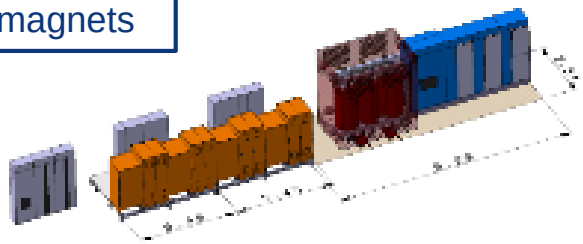


Transformer and distribution
RF LEFT SIDE

Transformers for
PC for magnets

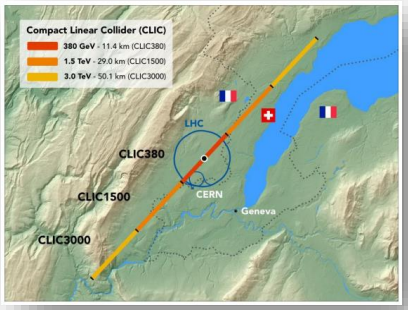


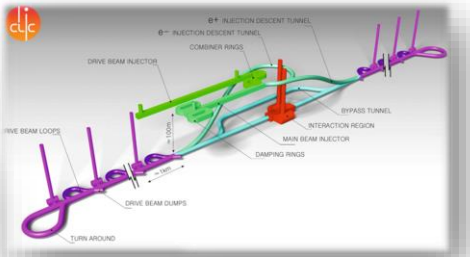


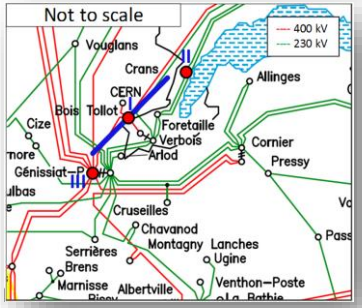


European Strategy for Particle Physics

CLIC







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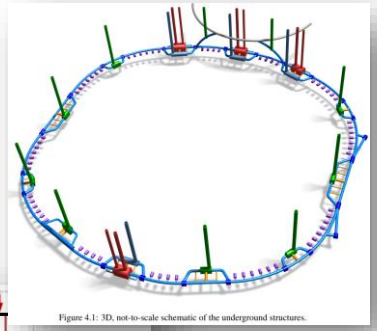


Figure 4.1: 3D, not-to-scale schematic of the underground structures.

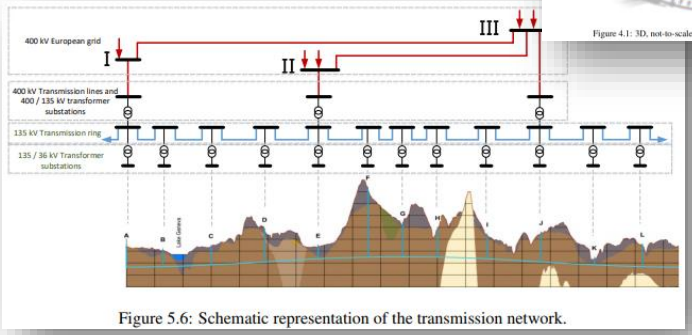


Figure 5.6: Schematic representation of the transmission network.

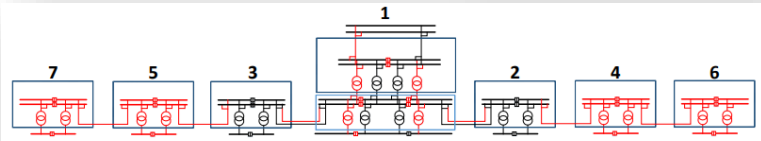


Figure 6.12: Transmission network baseline for 1.5 TeV. The extension from the 380 GeV stage to the 1.5 TeV stage is shown in red.

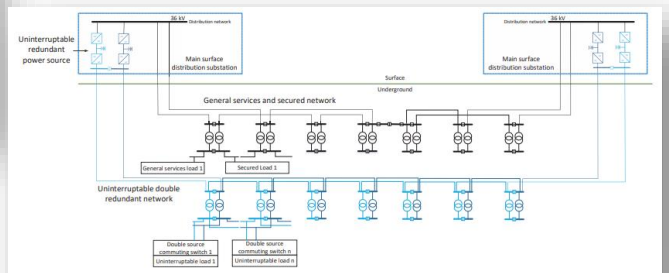
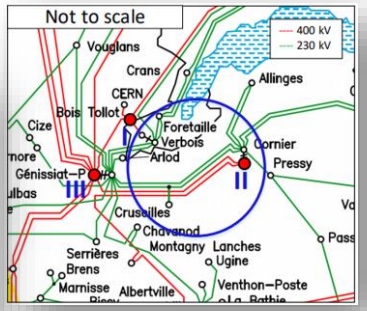


Figure 5.11: Functional scheme of the general services load network and the doubly redundant uninterruptable load network.



For more information:

- **CLIC:** https://clic.cern/european-strategy
- **FCC:** https://fcc-cdr.web.cern.ch/

Thank you for your attention

Questions