

CERN Electrical Infrastructure

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

Davide Bozzini, CERN Electrical Group



ENGINEERING
DEPARTMENT

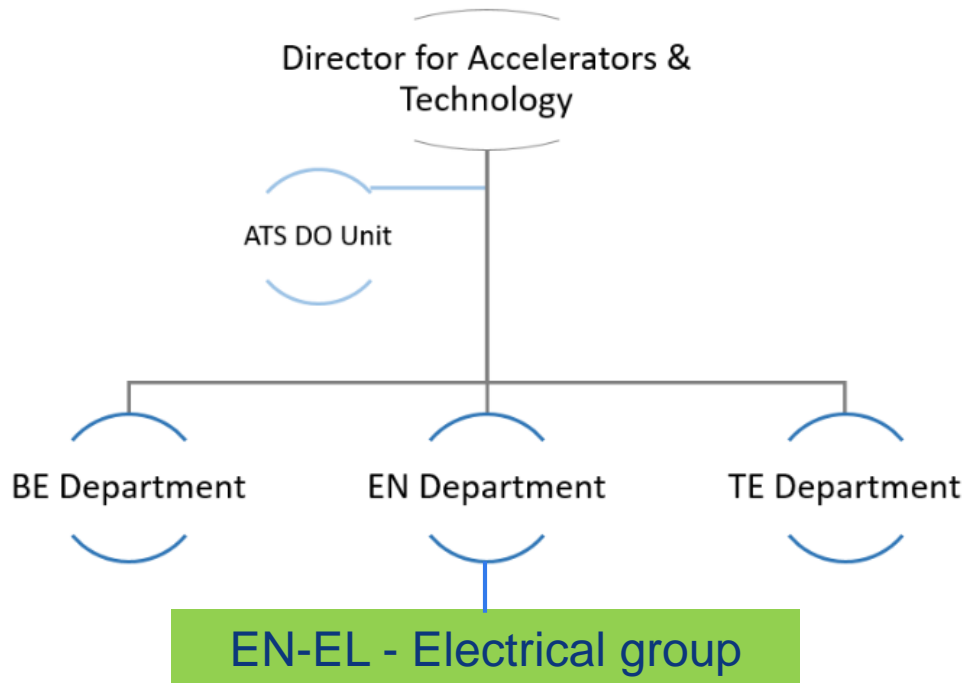
Agenda

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



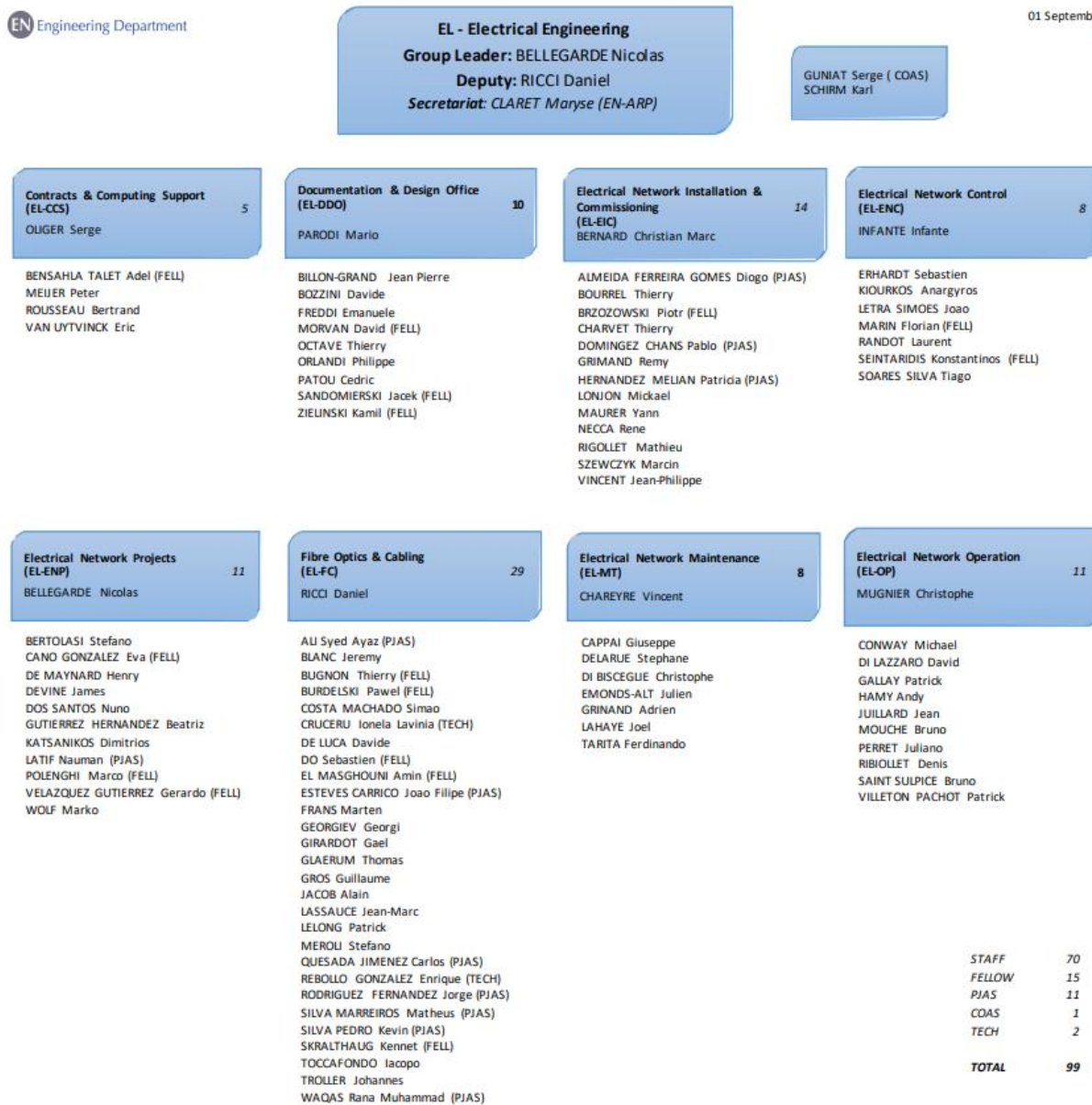
The [ATS-Directorate Office \(ATS-DO\)](#) is a unit of the Accelerator and Technology sector staffed by persons working on projects or studies such as HL-LHC, FCC, CLIC and EU activities.

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



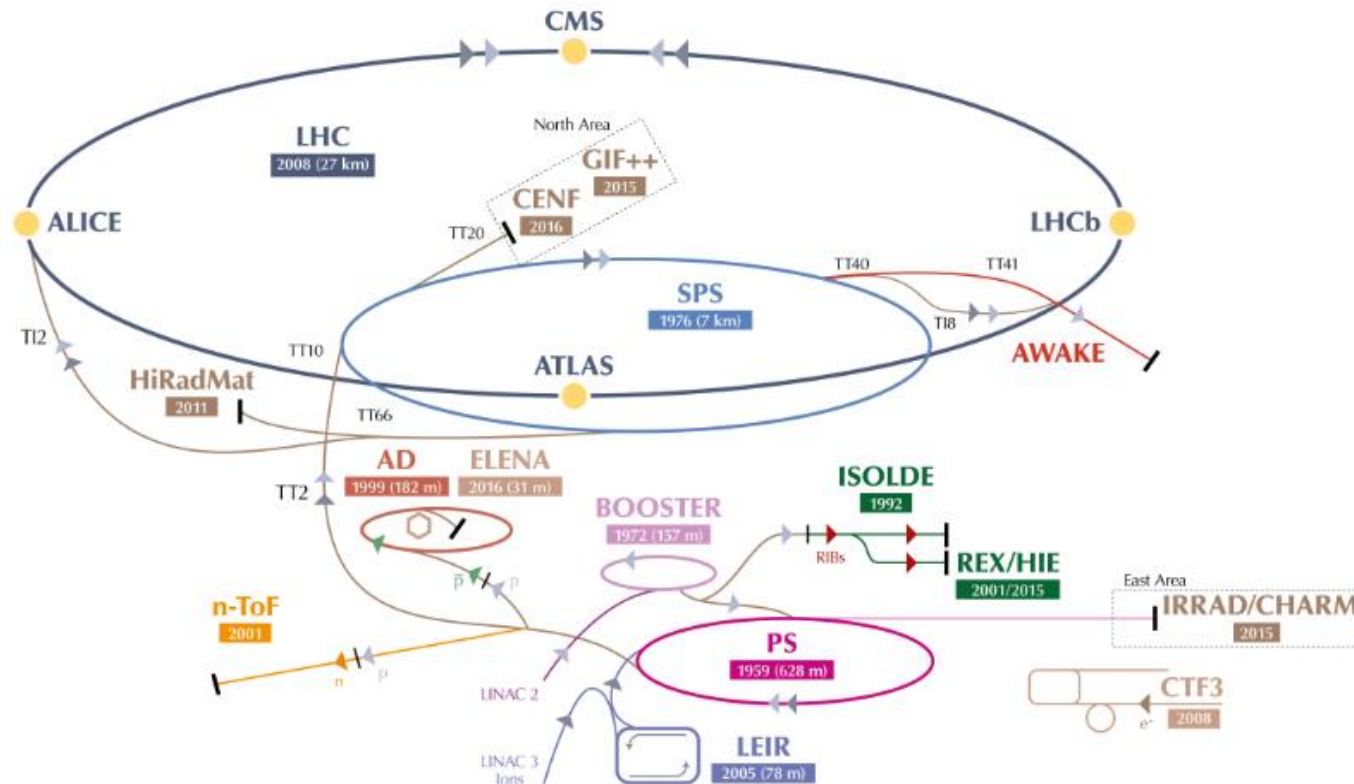
Personnel statistics on 1st February 2019

	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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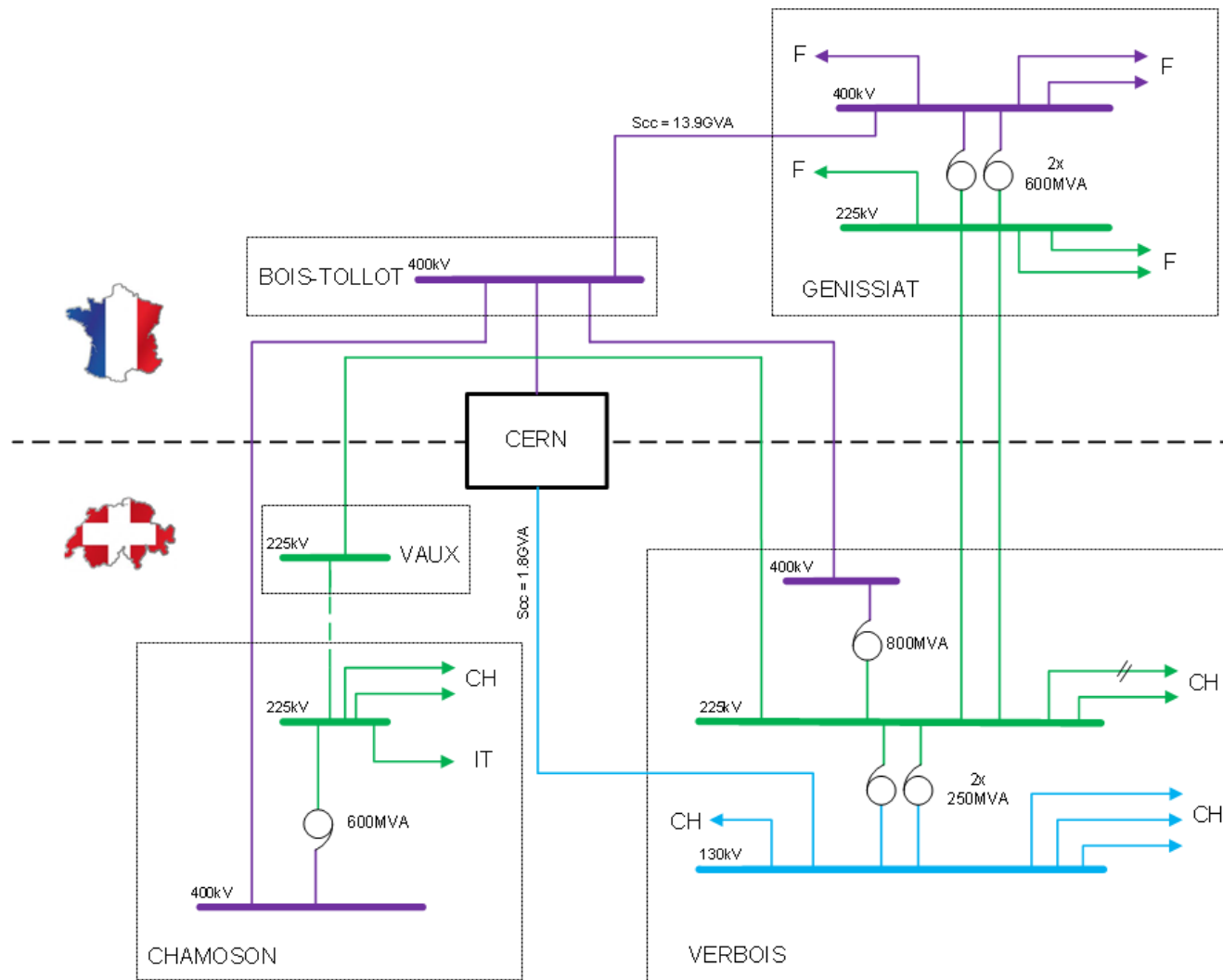
CERN accelerators complex



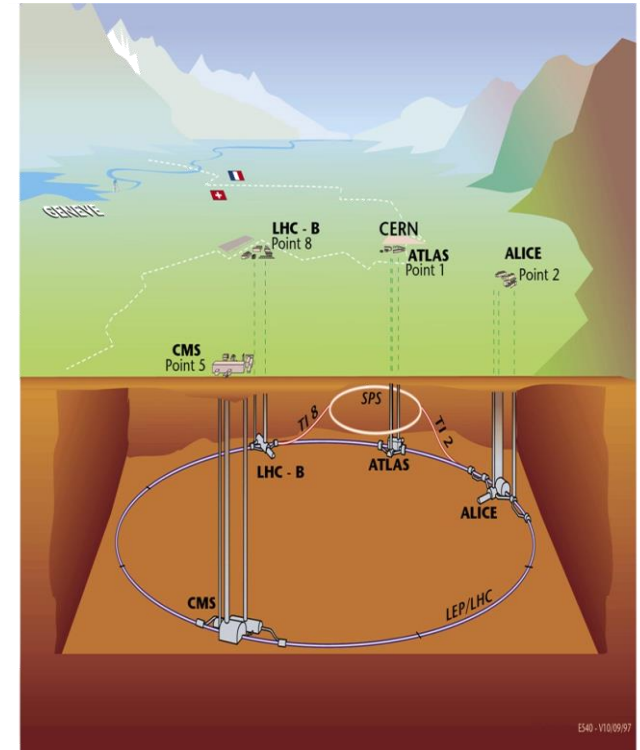
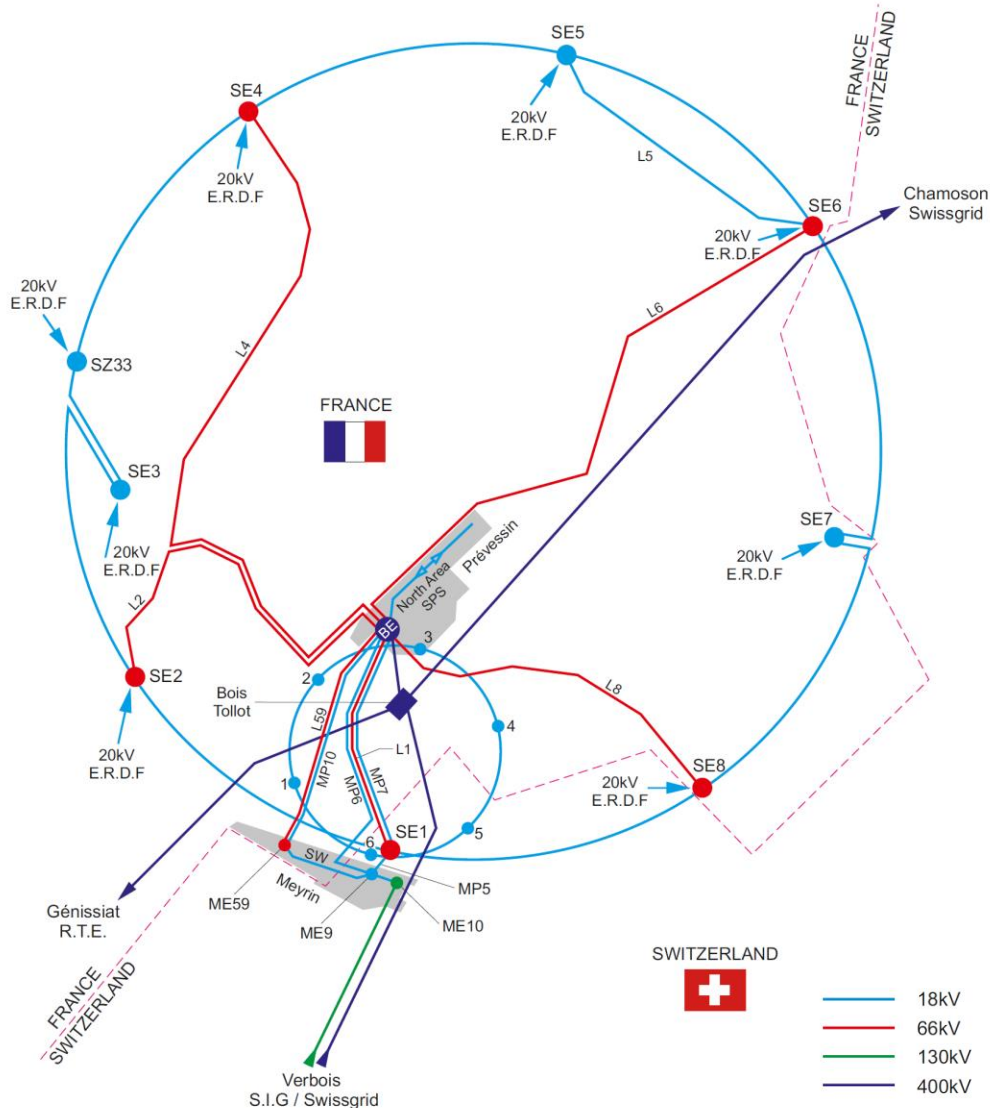
▶ p (protons)
 ▶ ions
 ▶ RIBs (Radioactive Ion Beams)
 ▶ n (neutrons)
 ▶ \bar{p} (antiprotons)
 ▶ e⁻ (electrons)

LHC Large Hadron Collider
 SPS Super Proton Synchrotron
 PS Proton Synchrotron
 AD Antiproton Decelerator
 CTF3 Clic Test Facility
 AWAKE Advanced WAKEfield Experiment
 ISOLDE Isotope Separator OnLine
 REX/HIE Radioactive Experiment/High Intensity and Energy ISOLDE
 LEIR Low Energy Ion Ring
 LINAC LINear ACcelerator
 n-ToF Neutrons Time Of Flight
 HiRadMat High-Radiation to Materials
 CHARM Cern High energy AcceleRator Mixed field facility
 IRRAD proton IRRADIation facility
 GIF++ Gamma Irradiation Facility
 CENF CEm Neutrino platForm

The Sources of Energy at CERN



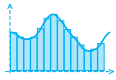
Electrical network: geographical extension



Voltage levels:

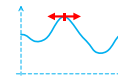
- 400 kV main incomer
- 66 kV transmission
- 18 kV distribution
- 3.3 kV motors
- 0.4 kV users

Electrical consumption: typical figure



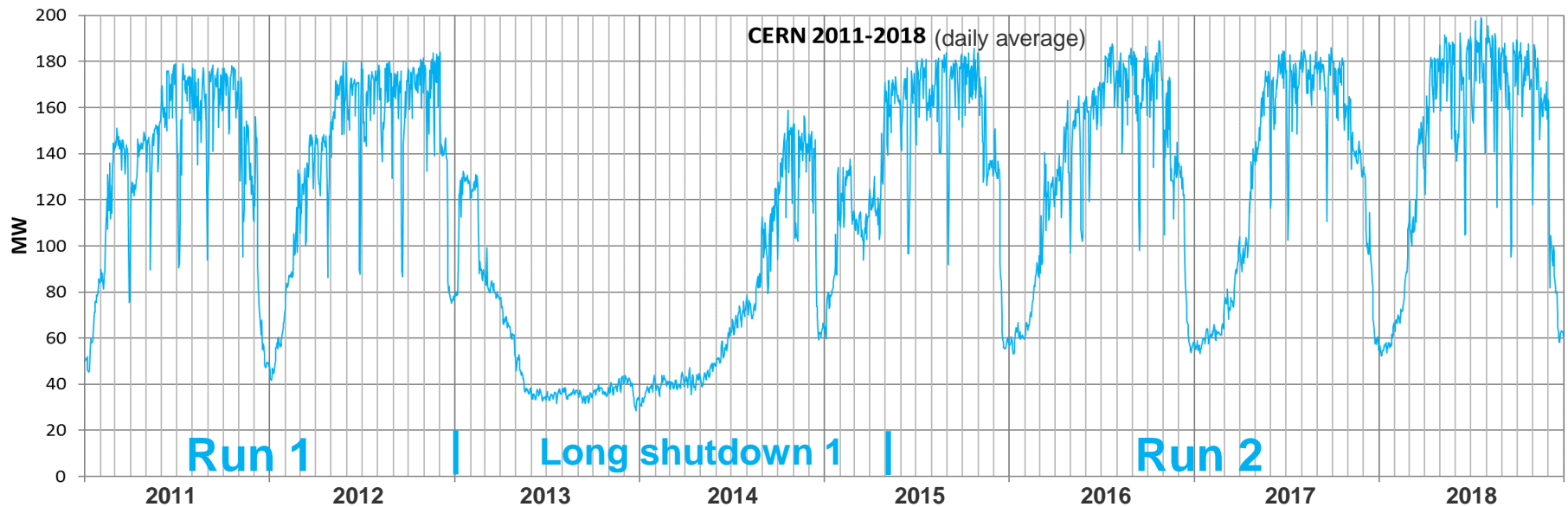
GWh (annual consumption)

- 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

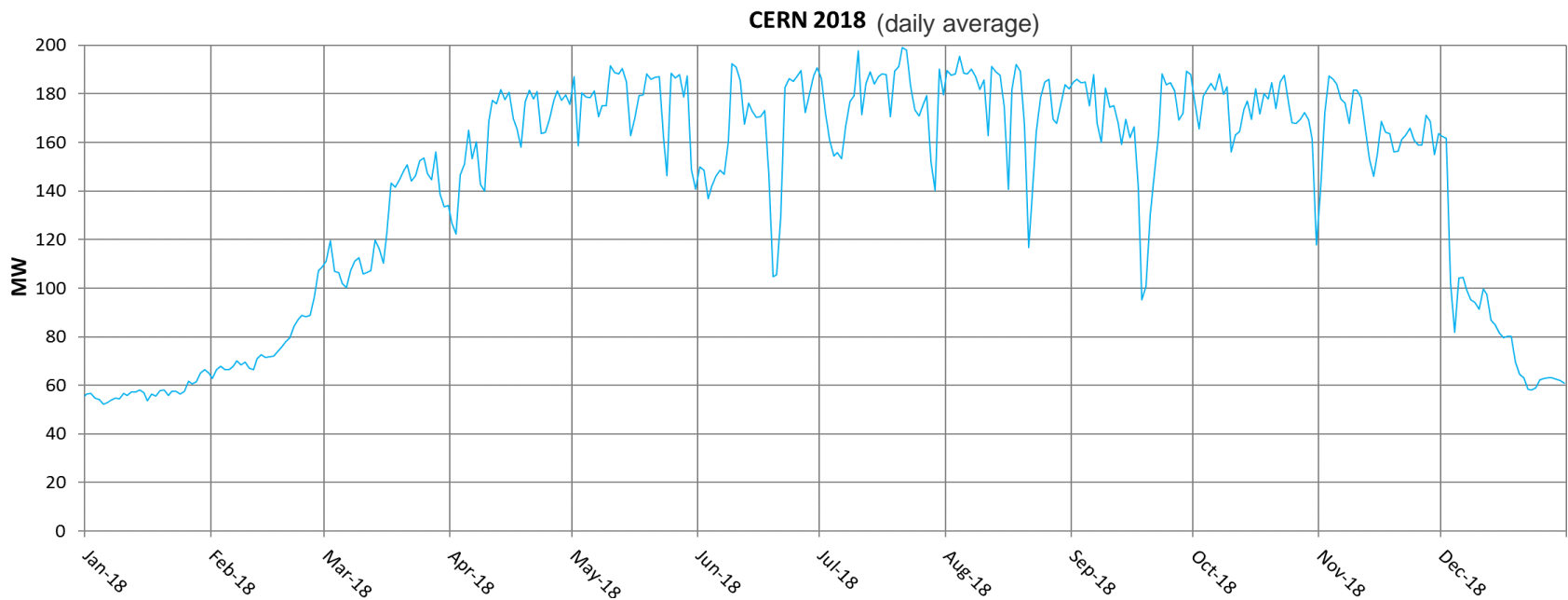
Electrical consumption: 2018 figures



- 1'251 GWh

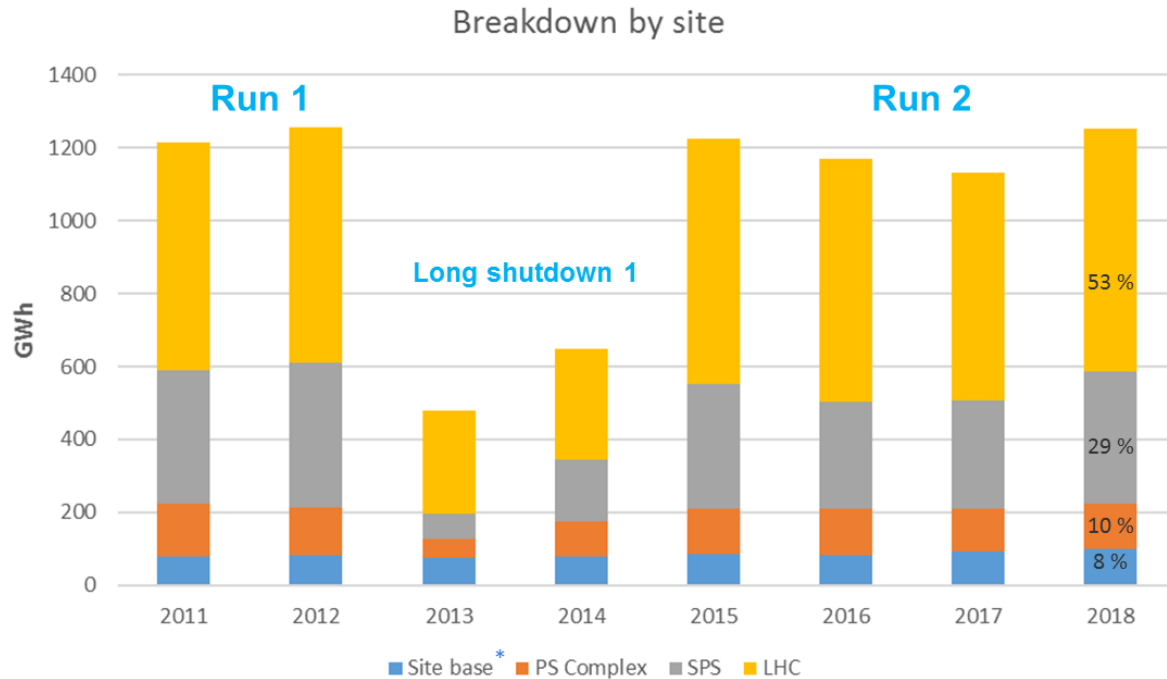


- 199 MW (daily average)
- 215 MW (10-min average)
- 320 MW (instantaneous)



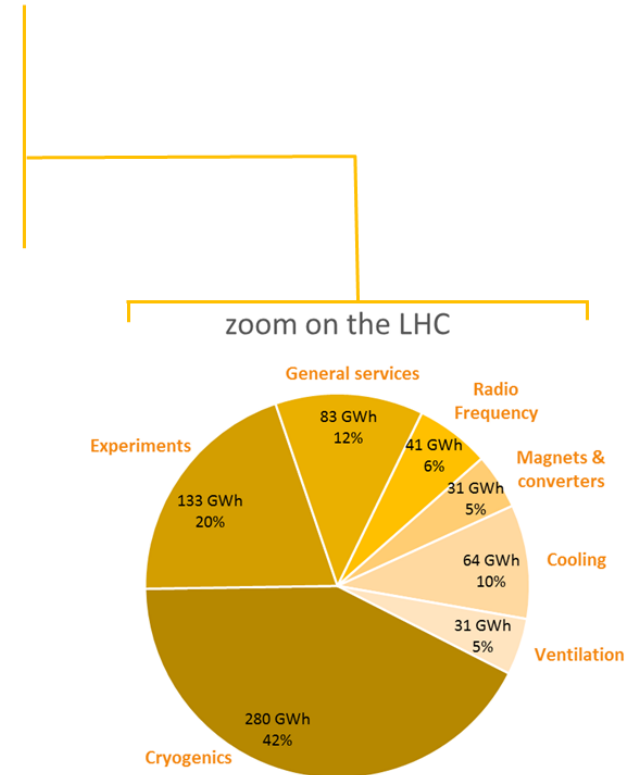
Courtesy B. Mouche / EN-EL

Electrical consumption: Zoom on LHC



* Site base =

- office buildings (Meyrin & Preessin 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

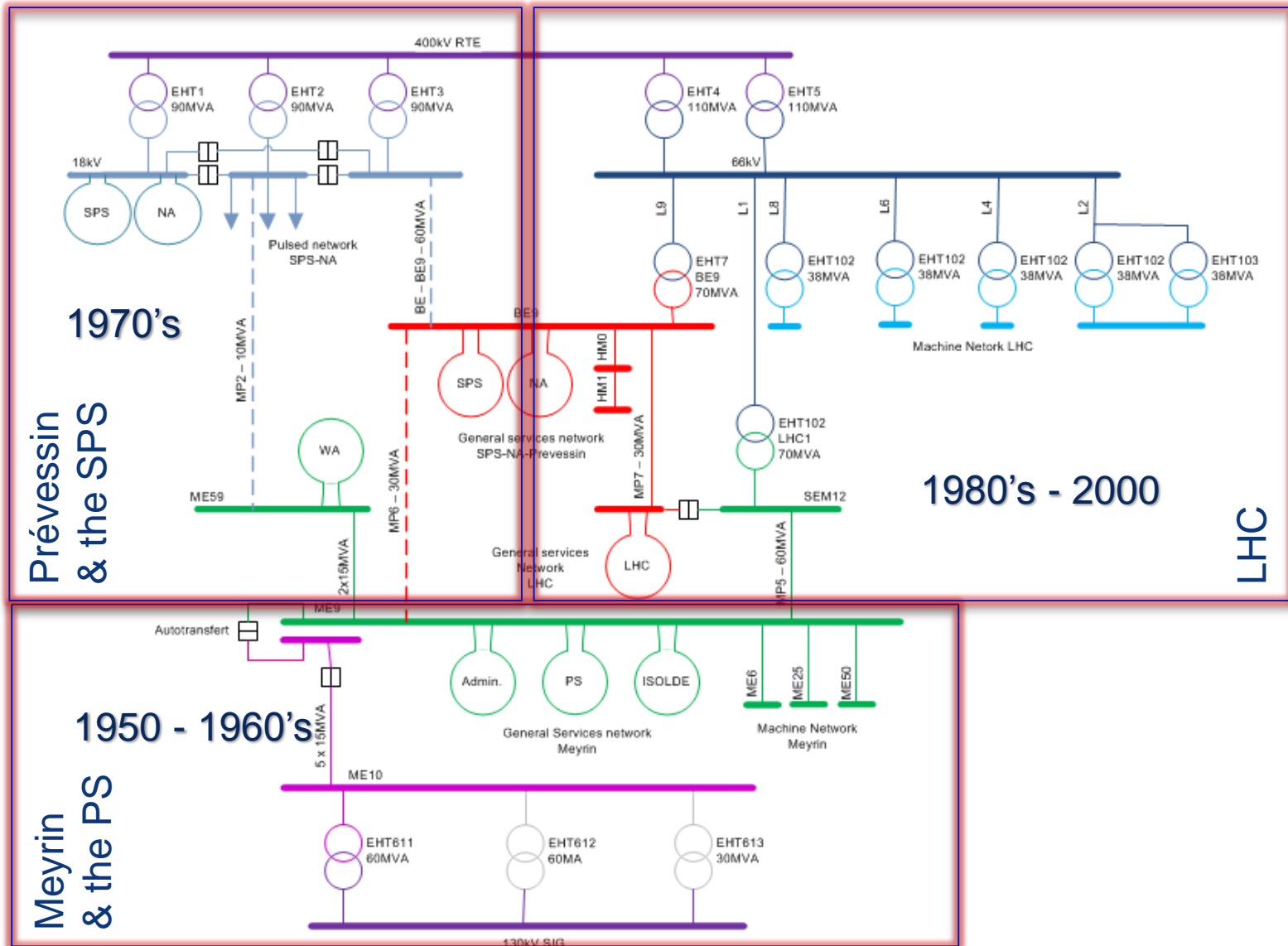
ENERGY

- Supply of energy

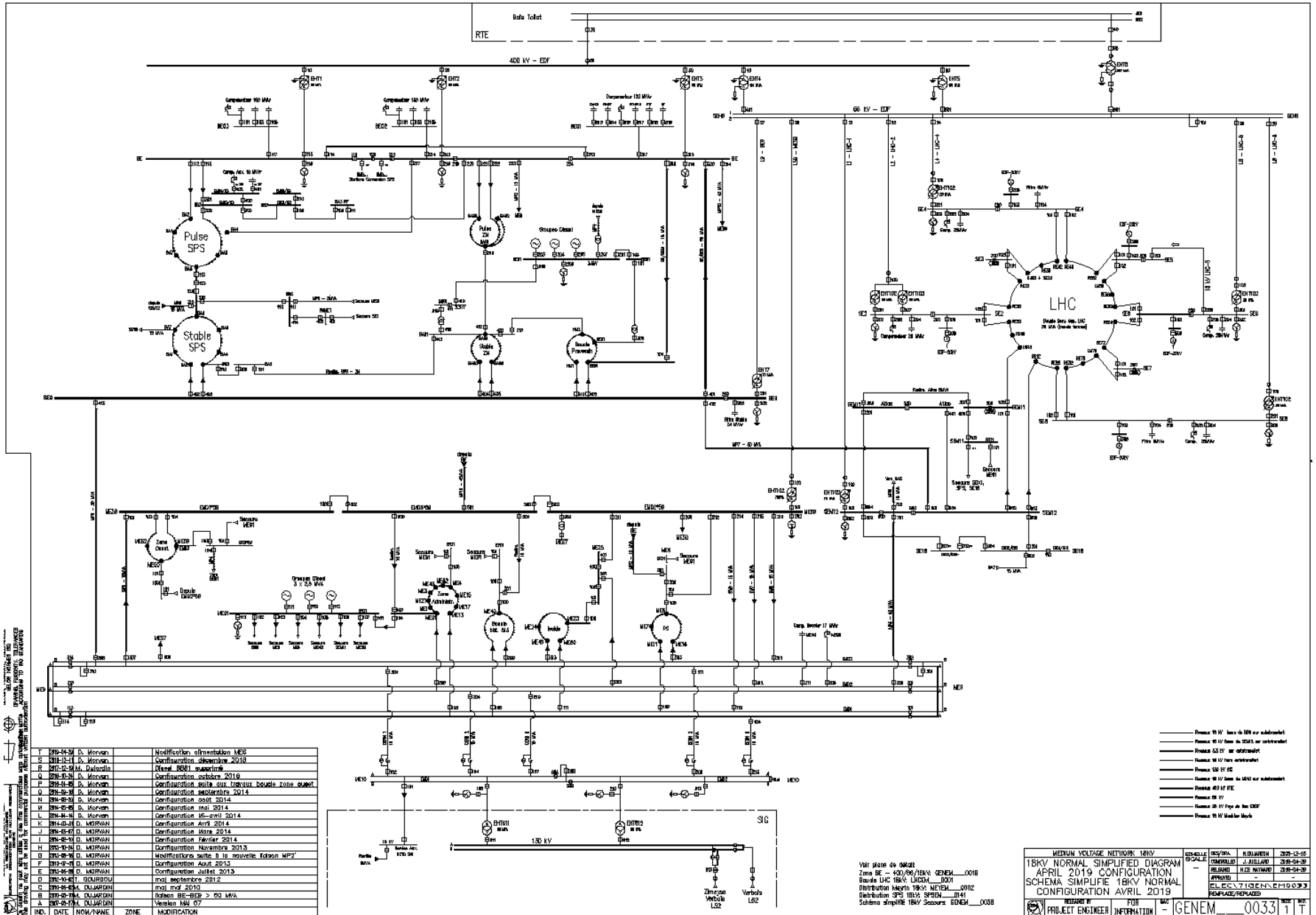
Type and quantity of equipment

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



NO.	DATE	NOV/PAGE	ZONE	INDICATION
T	2013-04-30	D. MORVAN		Modification alimentation MES
S	2013-11-11	D. MORVAN		Configuration septembre 2013
R	2013-12-10	M. DALPINO		Plan BSB1 supérieur
D	2013-12-10	D. MORVAN		Configuration octobre 2013
F	2014-05-15	D. MORVAN		Configuration suite aux travaux boucle zone externe
O	2014-06-10	D. MORVAN		Configuration septembre 2014
N	2014-09-24	D. MORVAN		Configuration août 2014
H	2014-09-24	D. MORVAN		Configuration mai 2014
L	2014-04-10	D. MORVAN		Configuration (6-avril) 2014
K	2014-04-10	D. MORVAN		Configuration Avril 2014
J	2014-04-10	D. MORVAN		Configuration Mars 2014
I	2014-02-20	D. MORVAN		Configuration février 2014
H	2013-12-10	D. MORVAN		Configuration novembre 2013
D	2013-09-16	D. MORVAN		Modification suite à la nouvelle Edison MP2
F	2013-07-24	D. MORVAN		Configuration Août 2013
E	2013-06-20	D. MORVAN		Configuration juillet 2013
D	2013-05-15	D. MORVAN		mod septembre 2012
C	2013-04-10	D. MORVAN		mod mai 2013
B	2013-03-10	D. MORVAN		Version BE-SEP > 60 MVA
A	2013-02-10	D. MORVAN		Version MAI 07
IND.				INDICATION

--- Phase 18 kV bus de BSB au substation
 --- Phase 66 kV bus de RTE au substation
 --- Phase 66 kV au substation
 --- Phase 18 kV bus substation
 --- Phase 18 kV bus de BSB au substation
 --- Phase 66 kV RTE
 --- Phase 66 kV bus de RTE
 --- Phase 18 kV bus de RTE
 --- Phase 18 kV bus de RTE

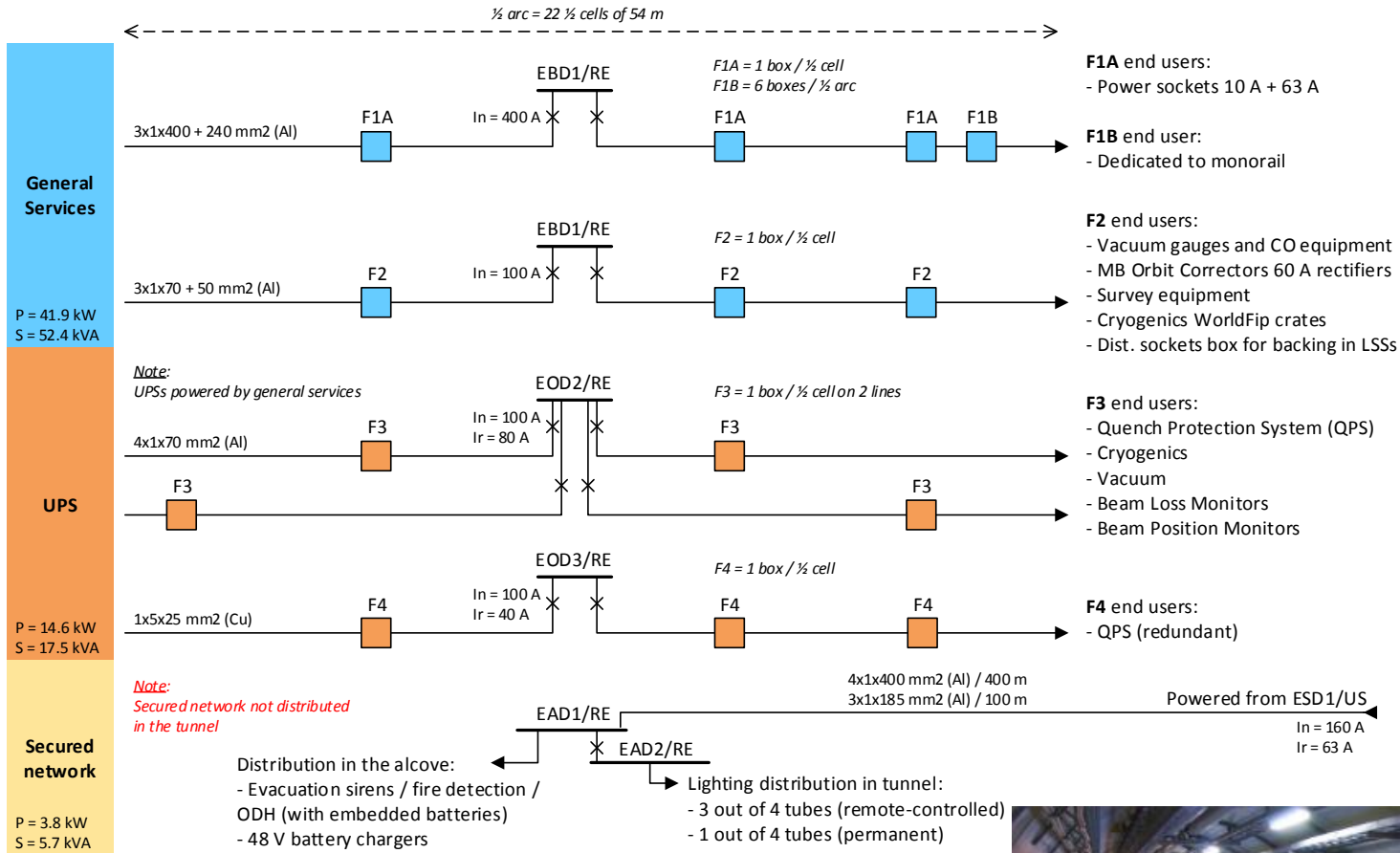
REVISE	DATE	INDICATION
0001	2013-12-10	
0002	2013-04-30	
0003	2013-04-30	

MEDIUM VOLTAGE NETWORK 18KV
 18KV NORMAL SIMPLIFIED DIAGRAM
 APRIL 2019 CONFIGURATION
 SCHEMA SIMPLIFIE 18KV NORMAL
 CONFIGURATION AVRIL 2019

VNI plan de 04/21
 Zone BE - 403/66/18kV GENEX_0018
 Boucle LHC 18kV LHC04_0001
 Distribution Merin 18kV NEM_0002
 Distribution SPS 18kV SPS01_0041
 Schéma simplifié 18kV Secours SDEM_0008

PROJECT ENGINEER INFORMATION = IGENEM 0033 117

Distribution in underground (LHC Tunnel)



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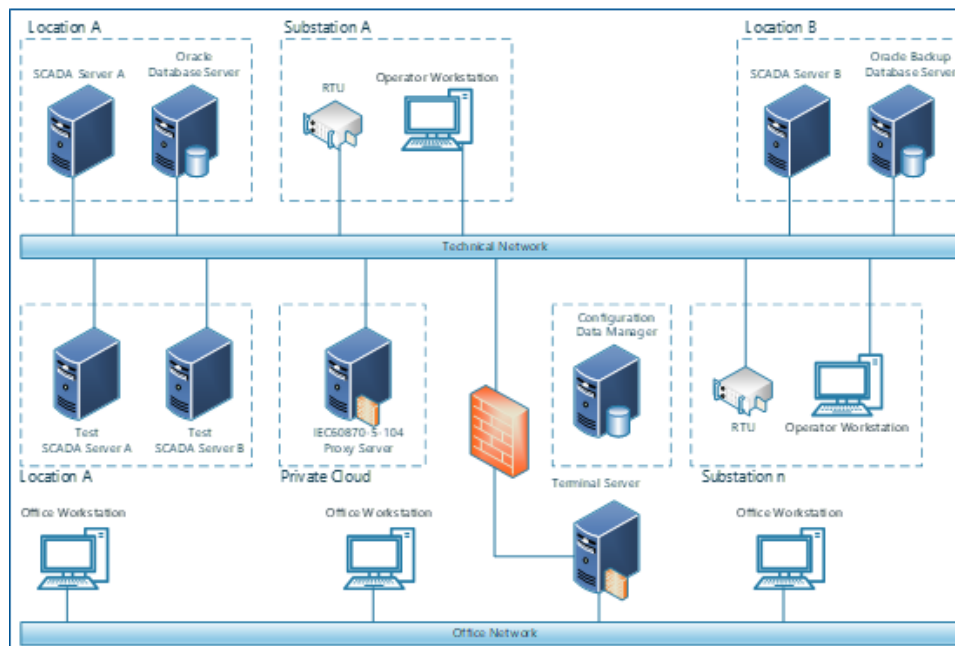
CERN ELECTRICAL NETWORK SUPERVISION System

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.



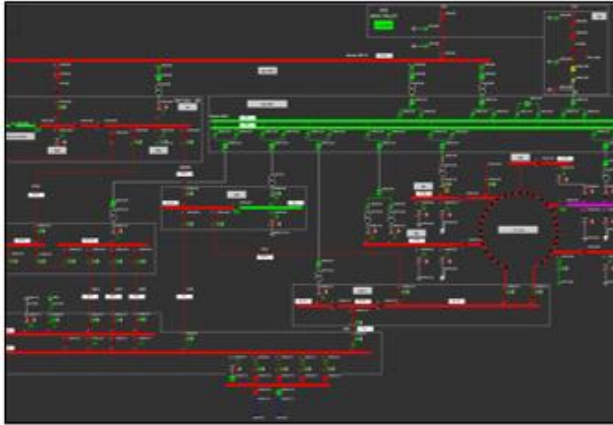
300 **remote I/O** stations are installed in electrical substations collecting digital input and output signals (status, alarms, open/close commands...) from electrical equipment.

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 **IEDs**, are microprocessor based digital devices and use the substation communication network for protection and data collection.

Courtesy S. Infante / EN-EL

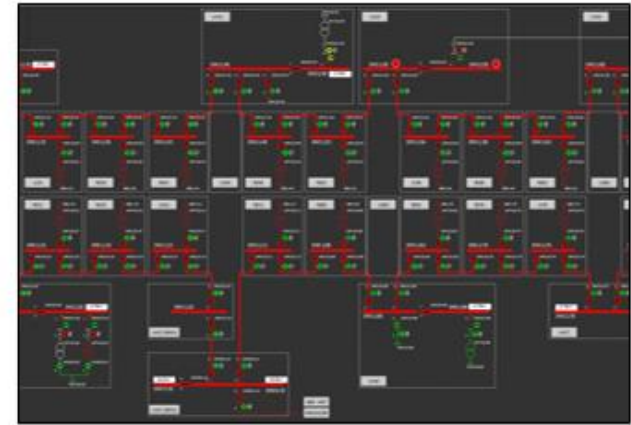
CERN ELECTRICAL NETWORK SUPERVISION System



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).



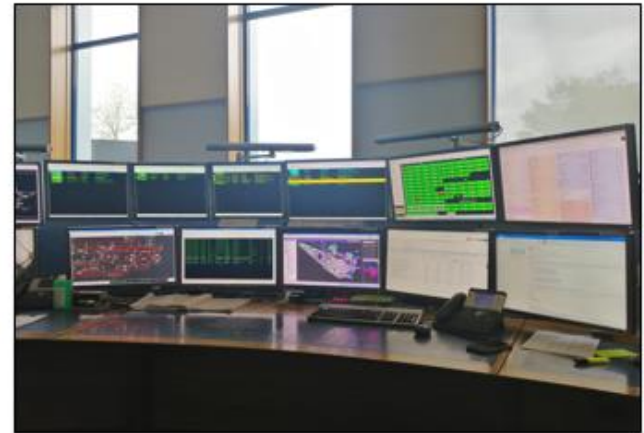
Single Line Diagram representing the 18kV network powering the LHC

Ref	Header/Ref 0	Header/Ref 1	Header/Ref 2	Device Name	Description	Alarm
009	Complex 00	MS0	Tranche 1/E020/7M E18001/7M	MS 00 Trip	MS 00 Trip	Warning
010	Complex 00	MS0	Tranche 1/E020/7M E18001/7M	Injection Plug 1 Insert	Injection Plug 1 Insert	Warning
008	Complex 00	MS0	Tranche 1/E020/7M E18001/7M	Injection Plug 2 Insert	Injection Plug 2 Insert	Warning
012	Complex 00	MS0	Tranche 1/E020/7M E18001/7M	Injection Plug 3 Insert	Injection Plug 3 Insert	Warning
007	18kV Zone 5	MS05	BT 180V zone5 18005/5M	Component abnormality P1	Component abnormality P1	Info
004	18kV Zone 4	MS04	Distribution UPS	DC Output OK	DC Output OK	OK
005	18kV Zone 4	MS04	Power 004/1804	Redundancy	Redundancy	Warning
006	18kV Zone 4	MS04	Power 004/1804	18kV 2 Communication Fault	18kV 2 Communication Fault	Fault
003	18kV Zone 4	MS04	Power 004/1804	Communication Status	Communication Status	Warning
001	18kV Zone 4	MS04	Power 004/1804	Speed/Current Error	Speed/Current Error	Warning
002	18kV Zone 4	MS04	Power 004/1804	Temperature Error	Temperature Error	Warning
000	18kV Zone 4	MS04	Power 004/1804	Speed/Current Error	Speed/Current Error	Warning
009	18kV Zone 5	MS05	MSV 5/18 18005/5M	High position	High position	OK
008	18kV Zone 5	MS05	MSV 5/18 18005/5M	Low position	Low position	Warning
007	18kV Zone 5	MS05	MSV 5/18 18005/5M	Communication 1/2	Communication 1/2	Warning
006	18kV Zone 5	MS05	MSV 5/18 18005/5M	Top High Level Position	Top High Level Position	Warning
010	18kV Zone 4	MS04	BT 180V zone 4 18004/4M	MS 04 Salinity	MS 04 Salinity	Warning
009	18kV Zone 4	MS04	Power 004/1804	Transformer Differential Ref	Transformer Differential Ref	Fault
008	18kV Zone 4	MS04	Power 004/1804	Oil Level Min. Top Change	Oil Level Min. Top Change	Fault
007	18kV Zone 4	MS04	Power 004/1804	Oil Level Max. Top Change	Oil Level Max. Top Change	Fault
012	18kV Zone 5	MS05	MSV 5/18 18005/5M	Top position	Top position	Warning
011	18kV Zone 5	MS05	MSV 5/18 18005/5M	Bottom position	Bottom position	Warning
008	18kV Zone 5	MS05	MSV 5/18 18005/5M	Ref 1 Abnormality	Ref 1 Abnormality	Fault
007	18kV Zone 5	MS05	Power 005/1805	Max Value Error	Max Value Error	Fault
006	18kV Zone 5	MS05	Power 005/1805	Min Value Error	Min Value Error	Fault
005	18kV Zone 5	MS05	Power 005/1805	Spring Discharged Delay Error	Spring Discharged Delay Error	Fault
004	18kV Zone 5	MS05	Power 005/1805	Max Value Error	Max Value Error	Fault

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

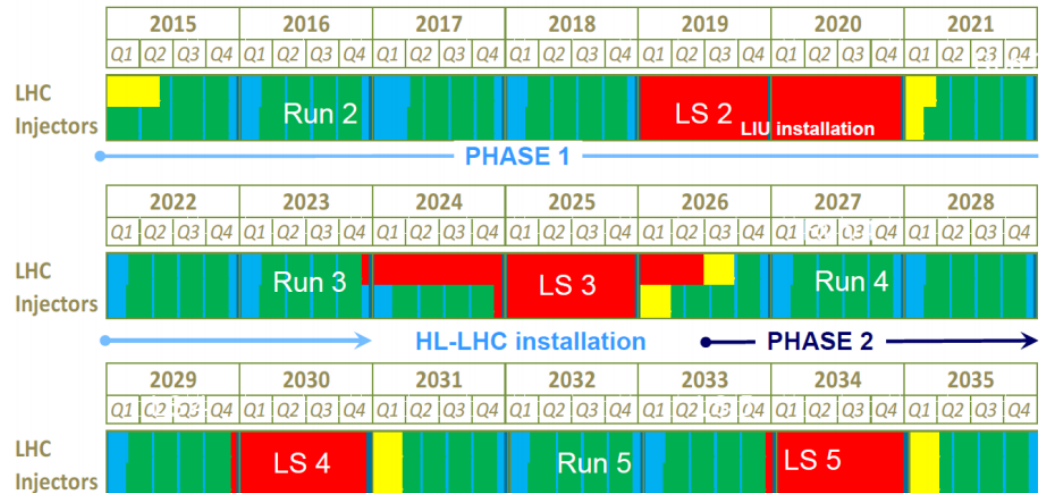
Typically **3 years physics run** followed by a **2 years long shutdown**

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

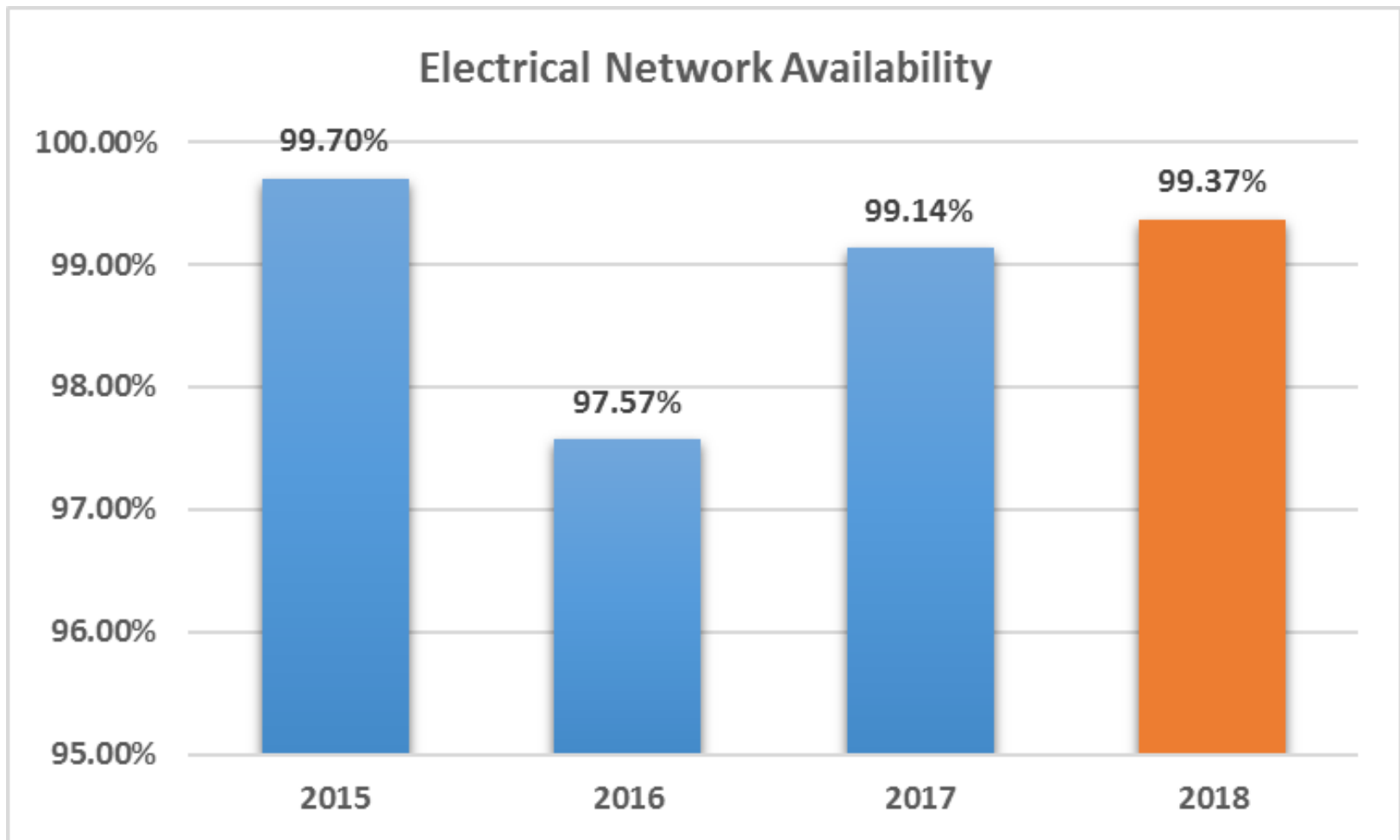
3 short technical stops (**3-5 days**) every year

LHC roadmap: according to MTP 2016-2020

LS2 starting in 2019 => 24 months + 3 months BC
 LS3 LHC: starting in 2024 => 30 months + 3 months BC
 Injectors: in 2025 => 13 months + 3 months BC



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

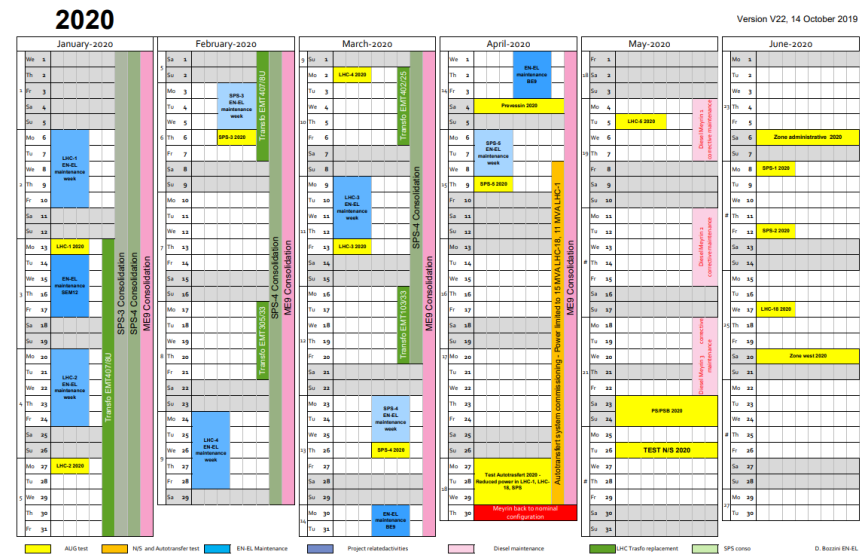
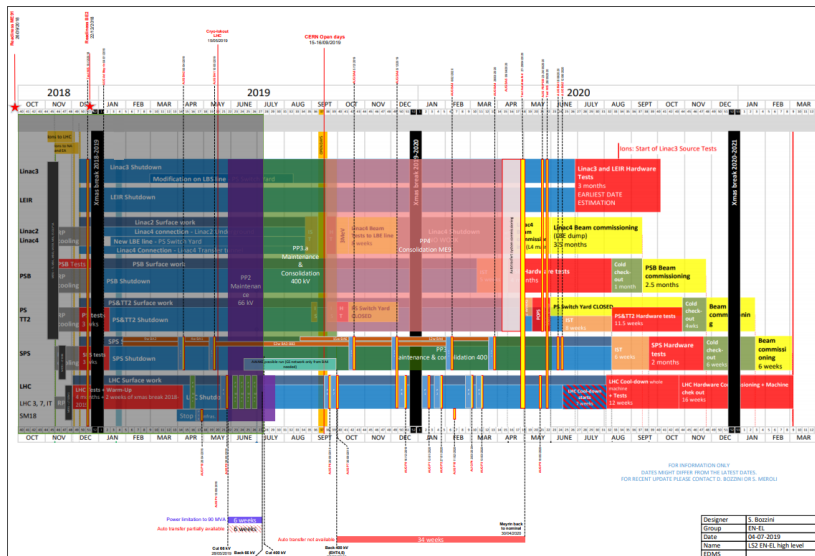


Activities coordination (Example of LS2)

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



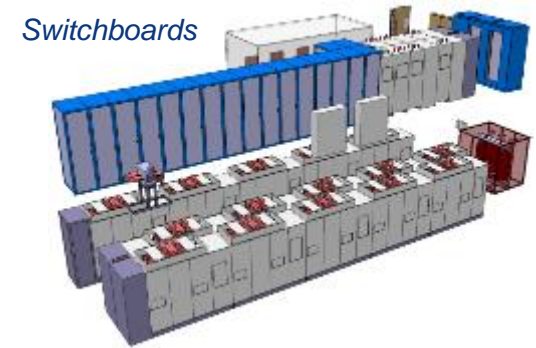
Version V22, 14 October 2019

Agenda

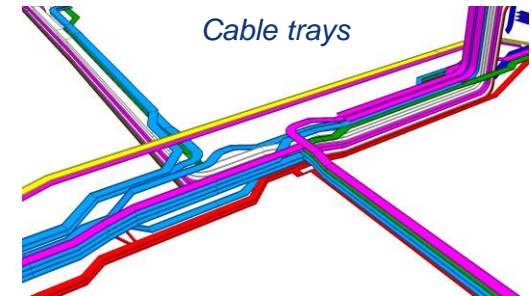
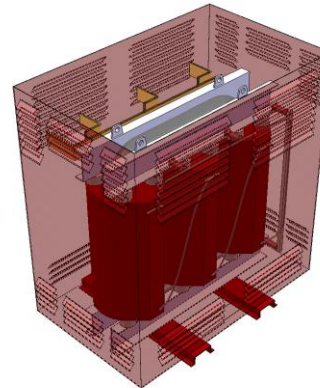
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Integration studies

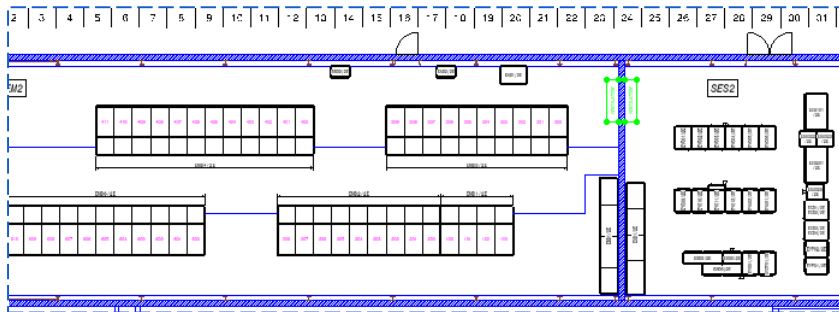
- 3D Integration:
 - Projects & substations
 - Integration studies of electrical equipment (racks) for all CERN users
 - Integration studies of cable trays for all CERN users
- 2D drawings for installation
- Building layouts



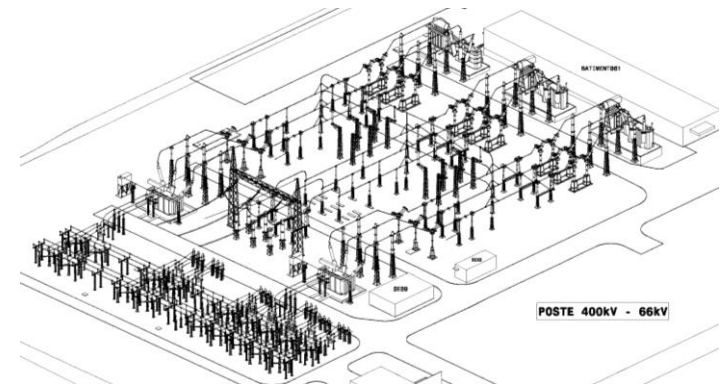
Transformers



Layouts



Substations



Integration studies

EL Electrical group

2D (Layouts)



2D (SLD)



3D



SMB, CV,

AUTODESK
REVIT



EN-ACE Integration group

3D



Repository
platform



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Example 1: Renovation of substations

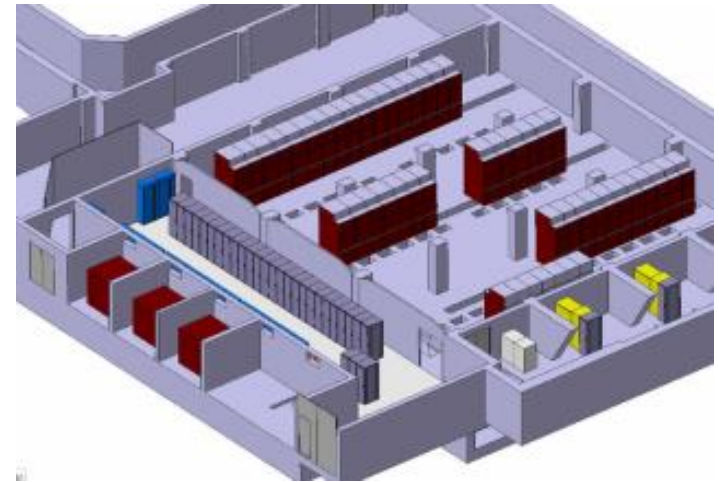


- Integration by CERN,
- Equipment provided via blanket contracts
- Construction via existing service contracts



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

Fibre Optics

DC-power
Cabling for
accelerator
magnets

Signal Cabling for CERN users

LS2 numbers

No. of cables	1400	1200	11500 (new)	20000 (removal)
Length [km]	120	24	800	900



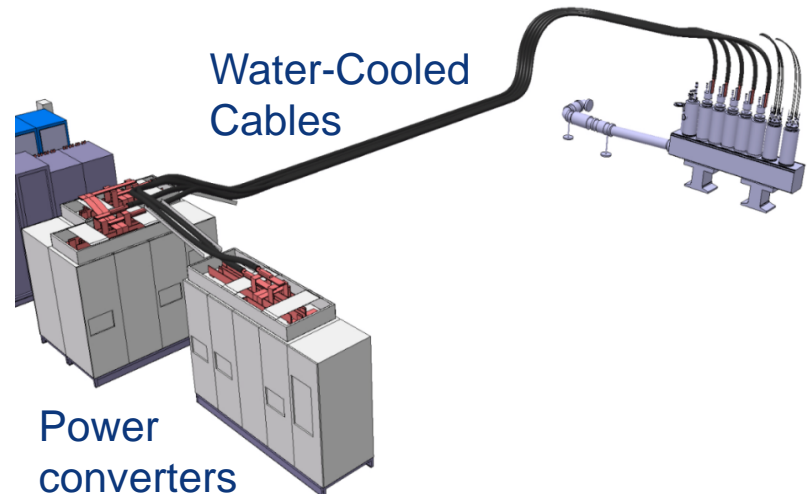
Example 7: Water-cooled cables

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



Agenda

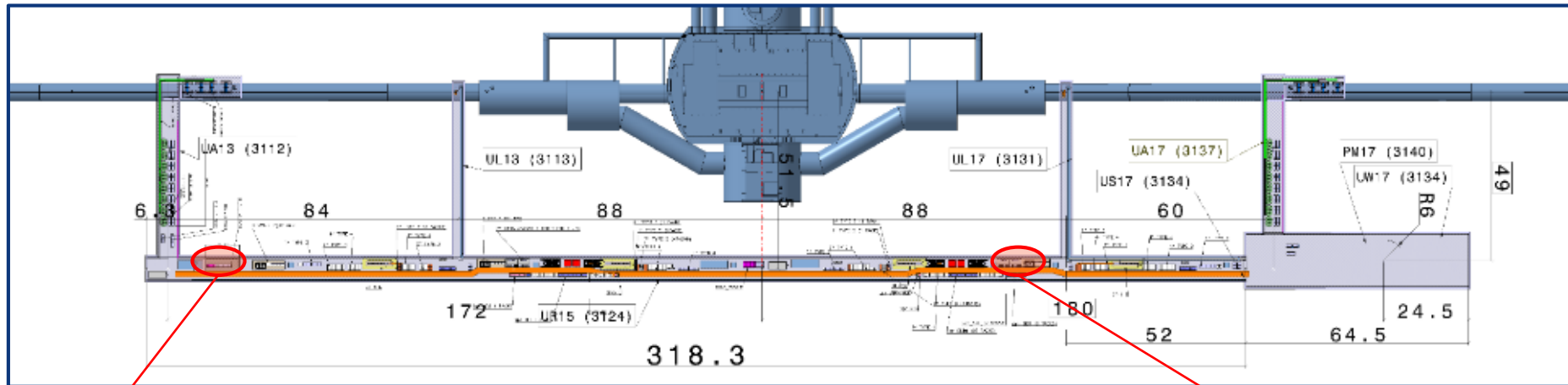
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Ongoing and future projects

Mid -Long term (2020 to):

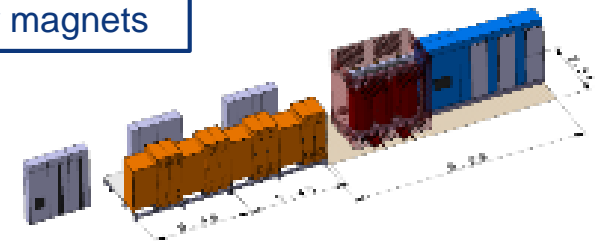
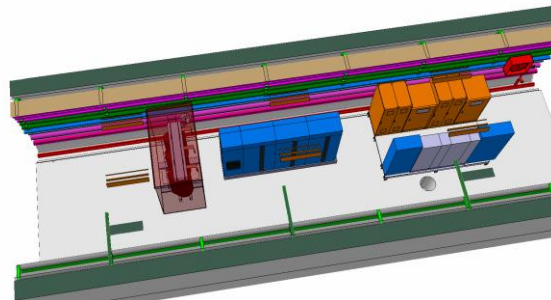
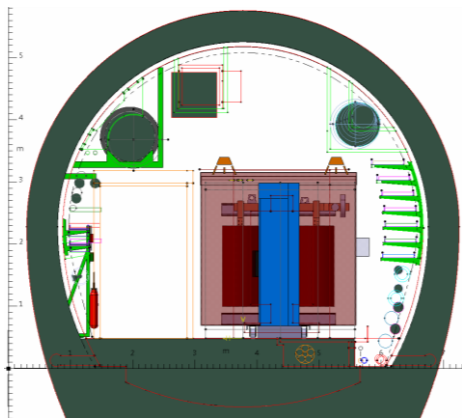
- Yearly consolidation and maintenance activities and approved projects design and execution
- HL-LHC, project approved study phase of electrical infrastructure well advanced, some works already planned during LS2
- According to the roadmap of the European Strategy for Particle Physics, CERN will hopefully host new accelerator infrastructures such as FCC, CLIC,.....

HL-LHC electrical infrastructure



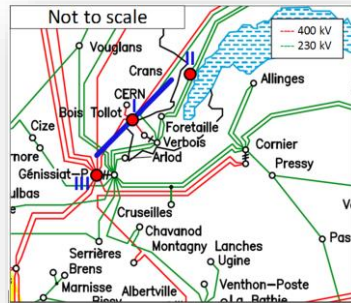
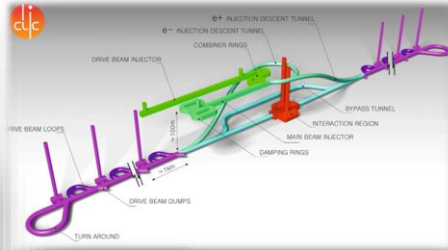
Transformer and distribution
RF LEFT SIDE

Transformers for
PC for magnets



European Strategy for Particle Physics

CLIC



FCC

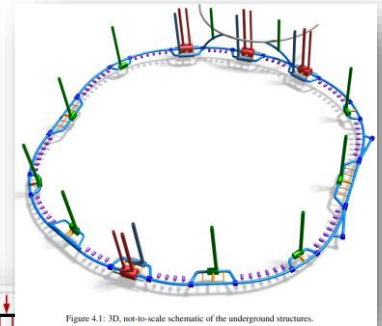


Figure 4.1: 3D, not-to-scale schematic of the underground structures.

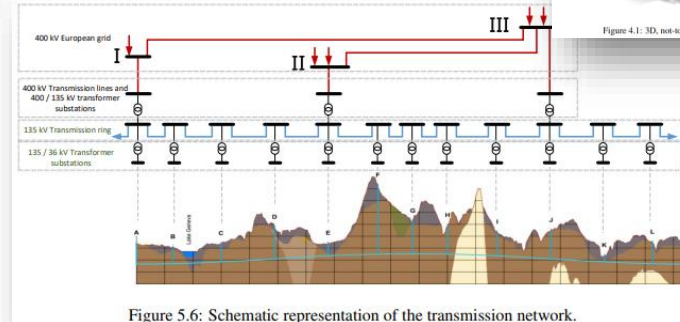


Figure 5.6: Schematic representation of the transmission network.

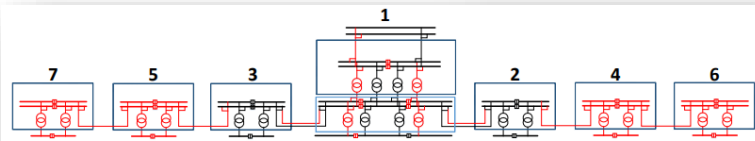
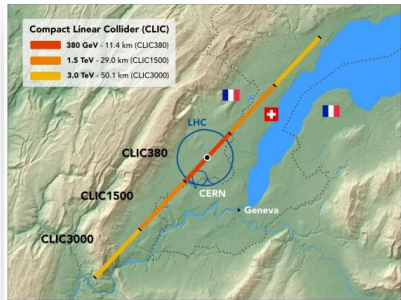


Figure 6.12: Transmission network baseline for 1.5 TeV. The extension from the 380 GeV stage to the 1.5 TeV stage is shown in red.

For more information:

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

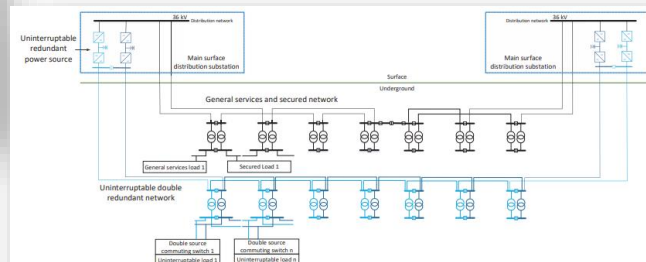
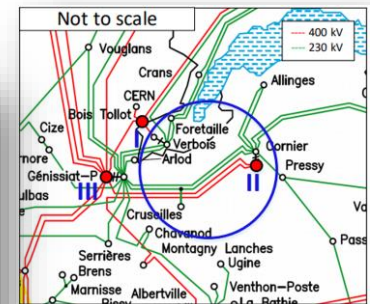


Figure 5.11: Functional scheme of the general services load network and the doubly redundant uninterruptible load network.



Thank you for your attention

Questions

