FUTURE CIRCULAR COLLIDER

NEW TECHNOLOGIES FOR ELECTRICAL TRANSMISSION AND DISTRIBUTION IN FCC

FCC Week – 11th June 2024
Charline MARCEL (CERN-EN/EL)

Outline

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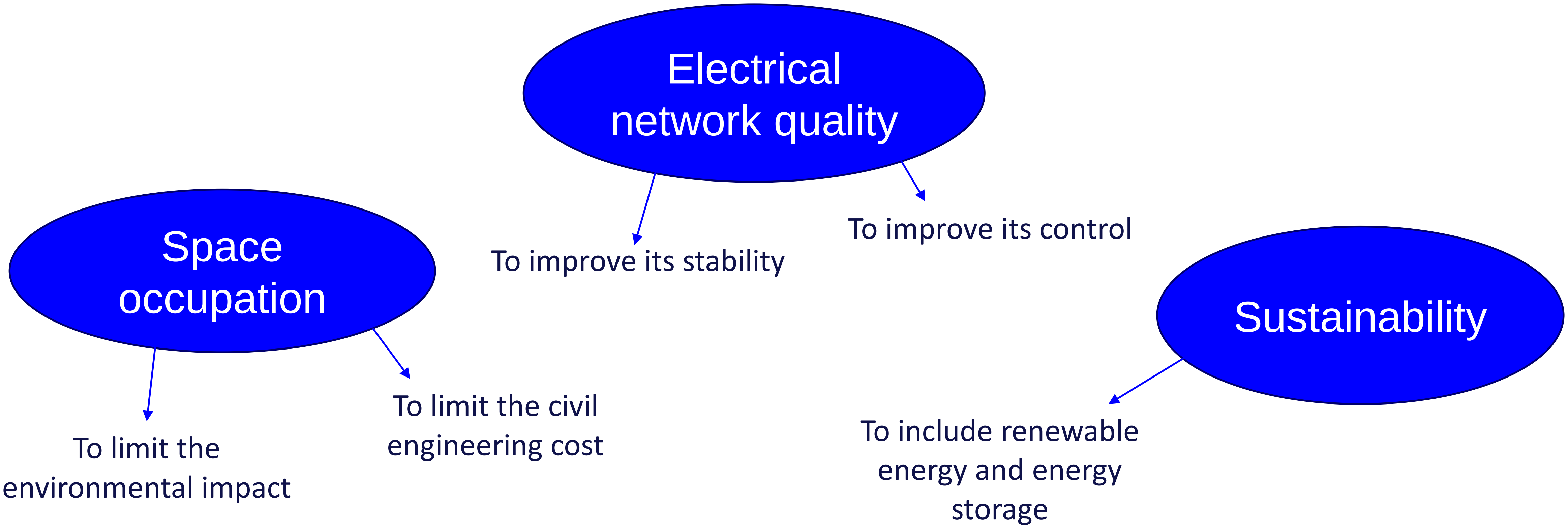
Introduction

FCC feasibility study: few challenges identified

➢ **The electrical network has a role to play in improving them**

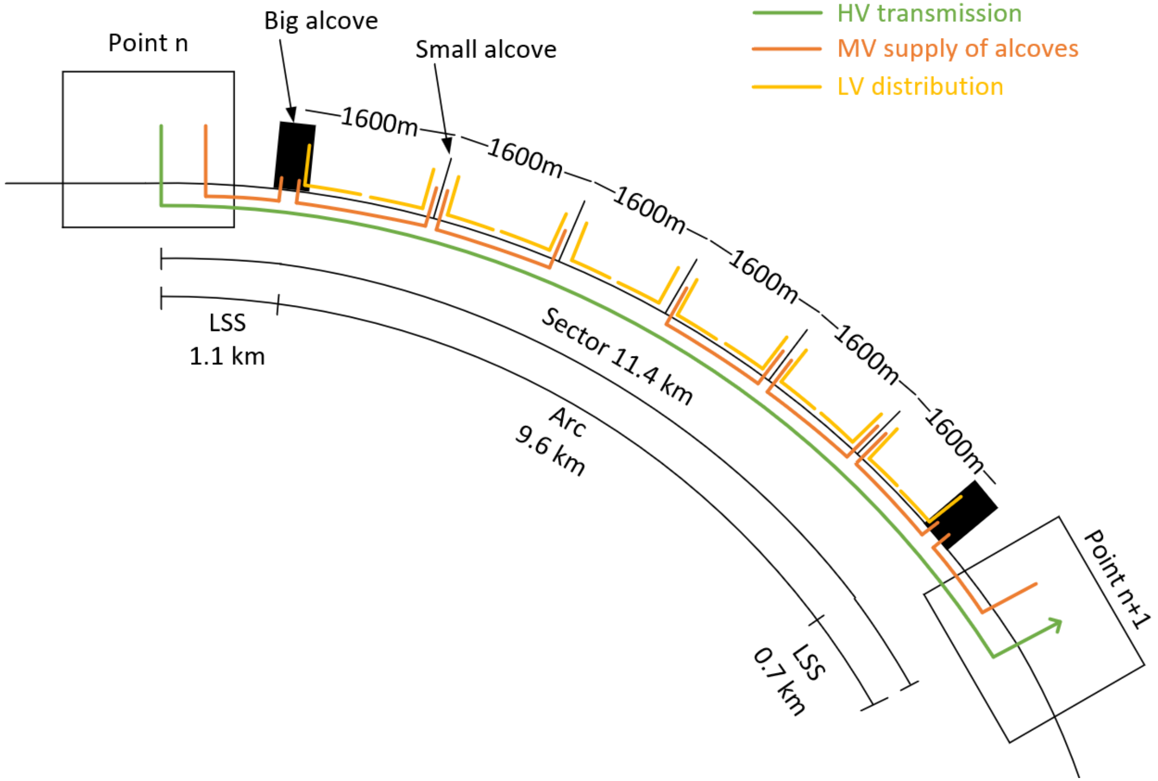


Limiting the cabling in the arc

Reminder of the cabling concept:

- Points are powered with HV transmission network passing through the tunnel
- Each point supplies the alcoves of half arc in MV, with the possibility to re-supply the second half
- Each alcove serves the 1,6km around it, 800m on both sides, with UPS supplies, general services, control cables
- The control and communication interconnections among alcoves is in Optical Fibre
- The power converters for the powering of the magnets are installed in the alcoves (mainly in the big alcoves but also in the small ones)

➢ **Many DC cables, for the powering of the magnets, in the arc coming from the alcoves**



First estimation done during the year showed that there would require: **6 cable trays of 500 mm** (for LV & MV cables, signal cables and optical fibres) **+ 5 cable trays of 400 mm** for DC cables **+ 2 cables trays of 200 mm** (for safety systems)

➢ Not enough place in the arc integration for this quantity of cable trays, study to optimize the cabling

Limiting the cabling in the arc

Update of the cables needs from 2023:

Users' needs (with preliminary design concept), **non-exhaustive list**:

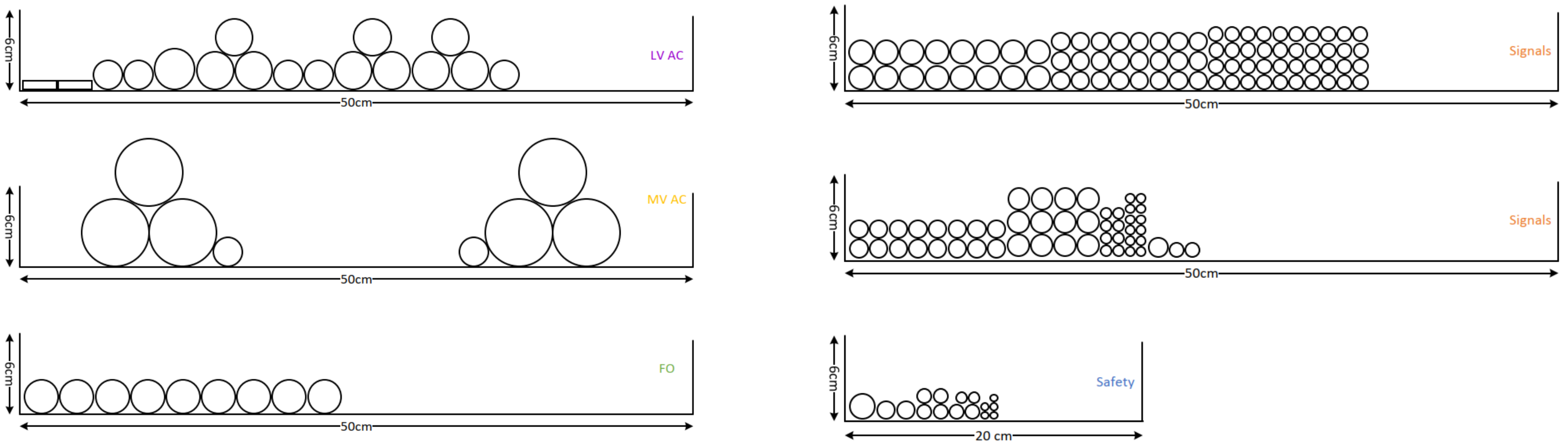
User	Load	Cable tray	Description of type	Diameter of the cable (mm)	Number of lines in the tunnel cross section
VSC	ion pumps	Signals	1x 0,63(HV) + 2x 0,25 mm2 Cu	d=10,7	28
	NEG (power)	Signals	3x 2,5 mm2 Cu	d=13	16
	Penning	Signals	3-axis 0,8/8,4 mm Cu	d=10,3	12
	Pirani	Signals	1x 4x1 mm2 Cu	d=6,5	12
	BA power	Signals	6x 2x0,75 mm2 Cu	d=14,5	6
	BA collector	Signals	3-axis 0,5/5,7 mm Cu	d=7	6
	Sector valve	Signals	6x 2x0,75 mm2 Cu	d=14,5	6
	Profibus	Signals	2x 1x0,35 mm2 Cu	d=8	1
AA	Sector doors	Safety	13x (2x 0,5 mm2)	d=17	1
	Fire doors - magnet	Safety	2x 1,5 mm2	d=10,5	3
	Fire doors - position contacts	Safety	2x 1 mm2	d=5	3
	Fire doors - flashing lights	Safety	4x 1,5 mm2	d=10,5	3
	Call points - break-the-glass	Safety	2x 1 mm2	d=5	2
	Call points - telephones	Safety	1x (4x 0,6 mm2)	d=7,4	2
	Evacuation - voice alarm	Safety	2x 2,5 mm2	d=13	2
CV	Fancoils	Signals	1x 70 mm2	d=16,6	16
	Dampers	Signals	1x 35 mm2	d=12,1	21
	Valves & other equipments	Signals	1x 35 mm2	d=12,1	3
RP	Radiation detectors (ttbar phase only)	Safety	2 x CEH50 + 2 x (2 x 0.22 mm2)	d=9,5	2
MPE	WIC fieldbus	Signals	1x 50 mm2	d=14	4
	BIS fibres	FO	1 duct	d=25	1
BE	no idea yet				
BI	no idea yet				
EPC	DC cables				
Others					

User	Load	Cable tray	Description of type	Diameter of the cable (mm)	Number of lines in the tunnel cross section
EL	HV transmission	HV cable	3x (1x 1200 mm2) Al	3x d=78	1
	MV power of alcoves	MV	3x (1x 400 mm2) + (1x 120 mm2) Cu	3x d=50 + d=21	1
	Secured power	MV	3x (1x 400 mm2) + (1x 120 mm2) Cu	3x d=50 + d=21	1
	Power outlets on G.S. network	LV	3x (1x 240 mm2) + (1x 120 mm2) Cu	3x d=27 + d=21	1
	Power outlets on UPS	LV	3x (1x 240 mm2) + (1x 120 mm2) Cu	3x d=27 + d=21	2
	Classic lighting	LV	(5x 16 mm2) Cu	d=30	1
	Emergency lighting	Safety	(5x 2,5 mm2) Cu, flat cable	24 x 6 mm	2
	A.U. (emergency electrical stops link)	Safety	14x (2x 1 mm2) Cu	d=21	2
FO	Backbone	FO	3 cables (x24 fibres)	d=25	1
	Underground	FO	9 cables (x24 fibres)	d=25	2
	BI	FO	13 cables (x12 fibres) + 8 cables (x24 fibres)	d=25	4
	Sensing	FO	2 cables (x6 fibres)	d=25	1

If other users know their needs, don't hesitate to communicate them

Limiting the cabling in the arc

With the currently known cable needs:



+ HV cable

For more details, presentation on Thursday 13th June at 11:24am "FCC electrical grid and infrastructure: update" by M. Parodi

BUT, not all the needs are known yet and some concepts can still change, some margin must be taken to estimate the required number of cable trays:

- **1 cable tray for MV distribution**
- **2 cable trays for LV distribution**
- **1 cable tray for FO**
- **2 cable trays for signals cables**
- **2 cable trays (200 mm) for safety systems**

+ cable trays for DC cables

(number under study)

Opportunity of reducing the cabling: use as much Optical Fibres as possible.

Examples given:

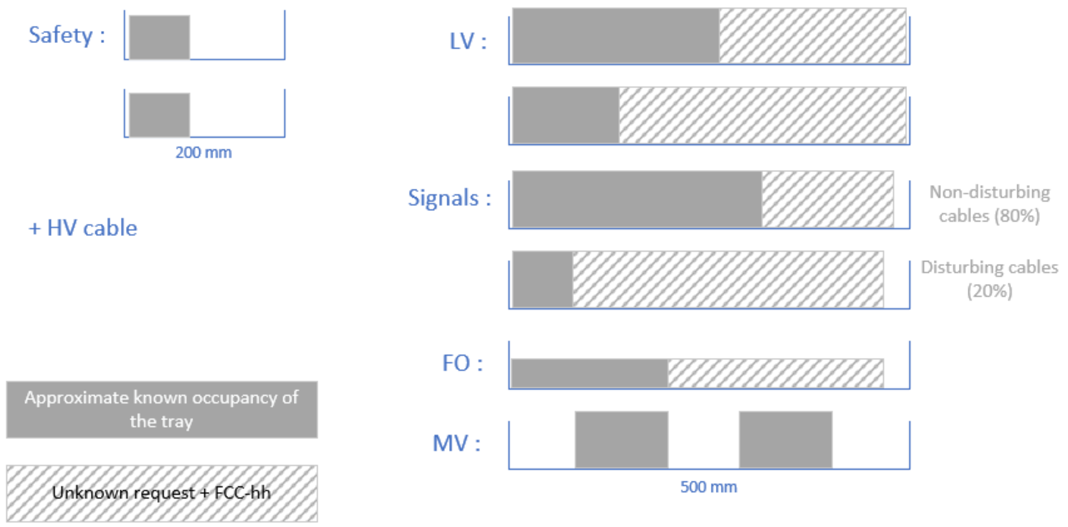
- In the HV cables for the control
- To replace signal cables (Copper2Fibre project)

Limiting the cabling in the arc

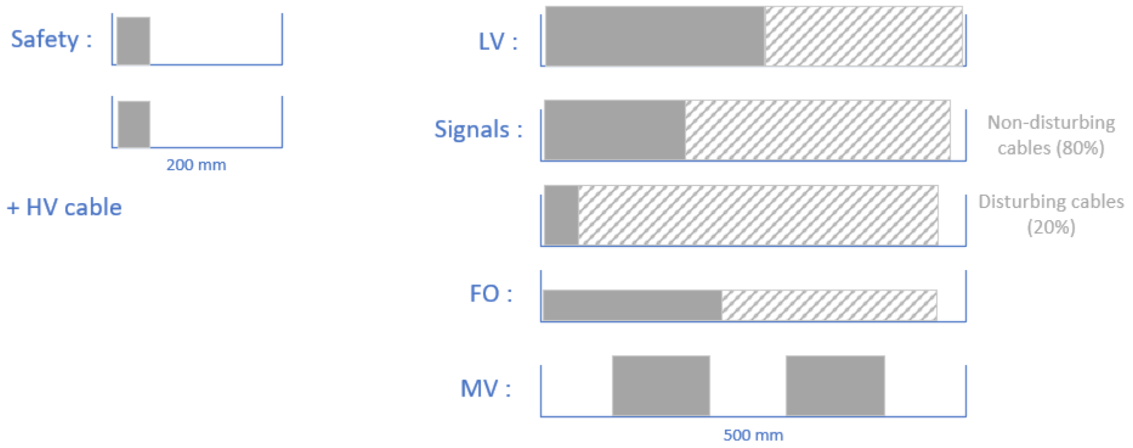
Limiting the cabling by optimizing the number of alcoves in the arc

Updated estimation of the cable trays needs, dependent on the number of alcoves:

For 7 alcoves per arc:



For 14 alcoves per arc:



+ Model of electrical equipment overall cost depending on the number of alcove, to include it in the global optimization

+ DC cables: under optimization, big impact on the quantity of cable trays

For more details, presentation on Tuesday 11th June at 4:14pm "Global Optimization" by B. Wicki

Limiting the impact of the substations on sites

Classic High Voltage substations: with AIS (Air Insulated Switchgears):

- A lot of equipment are required (disconnectors, circuit breakers, earthing switches, etc.)
- Great distances are required between the HV equipment

Example of BE2: 400 kV to 66 kV substation of CERN

~ 4,000 m²
(100 x 40 m)

Transformer 400/66 kV 220 MVA

400 kV side

66 kV side

Limiting the impact of the substations on sites

Need to use as little space as possible:

- On surface sites: to limit the environmental impact
- In underground infrastructures: to limit the civil engineering cost
- ➢ **Optimization required of the technologies used for the electrical substation and of their locations**

Use of GIS: Gas Insulated Switchgear:

Compact metal encapsulated switchgear consisting of high-voltage components (as circuit-breakers, disconnectors, etc.) which can be safely operated indoor.

The components are housed in shielded chambers with barrier devices and submerged in gas (e.g. SF_6).

Benefits:

- Secure working place
- Protected from external disturbances (e.g. lightnings)
- Minimize the footprint
- Minimize the installation time

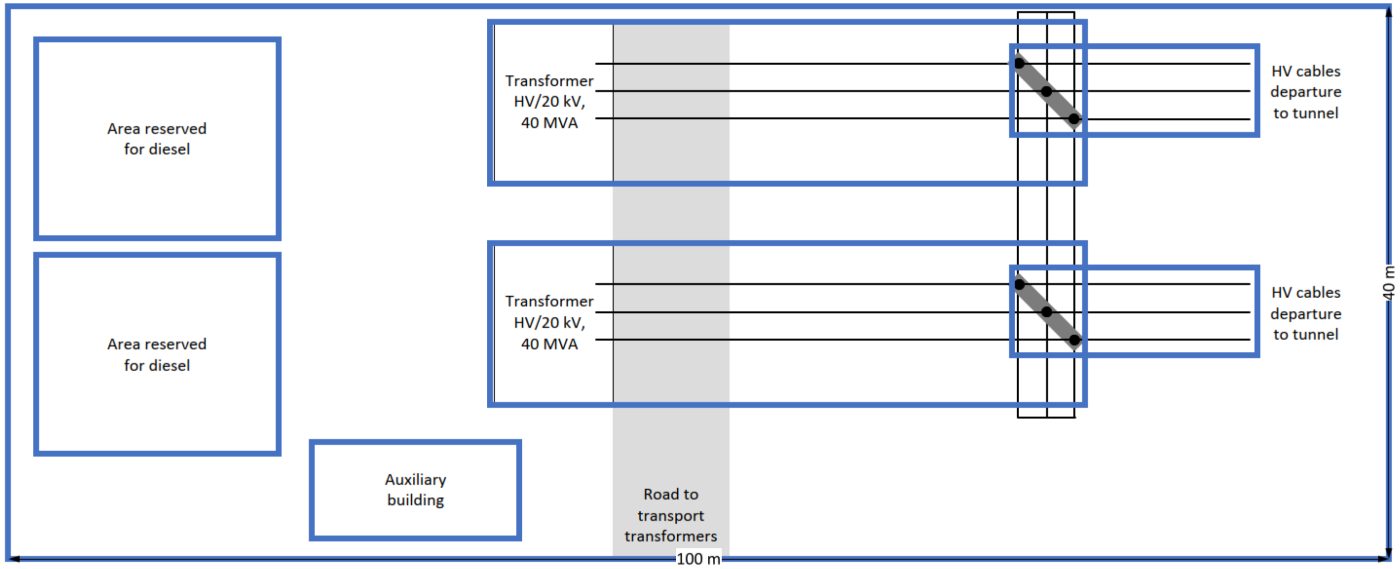
Disadvantages:

- More expensive than AIS
- Use of greenhouse gas (but green gas solutions are being developed)

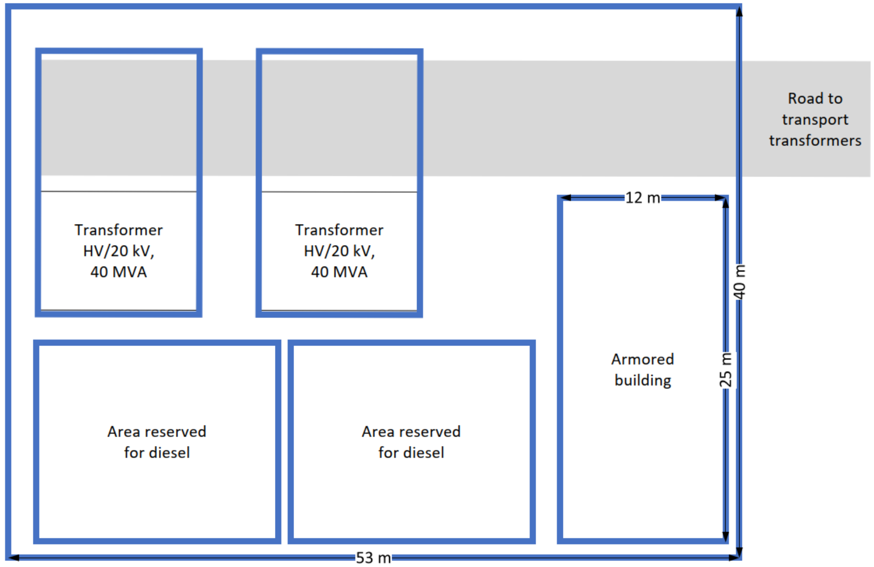
Limiting the impact of the substations on sites

For the substations at all points, without the connections to RTE's grid at 400 & 225 kV:

With AIS (~ 4,000 m²):



With GIS (~ 2,000 m²):



	GIS	AIS
Overall surface	40 m x 53 m	40 m x 100 m
	2120 m²	4000 m²
Estimated price (kEUR) (without the cost of transformers)	2544	1701

(for HV = 63 kV)

On the HV side (here 63 kV), using GIS instead of AIS has such impacts:

- **Footprint of the substation: divided by ~ 2**
- **Cost of the substation: multiplied by ~ 1.5**

Optimizing the location and technology of the substations

Indeed, HV substations with GIS can also be installed underground

The goal is to find the optimum between:

- **AIS on surface**
- **GIS on surface**
- **GIS underground**

Some auxiliary cost for underground installation still to be assessed (logistics or safety related)
But with much lower impact than civil works

	63kV		
	AIS surface	GIS surface	GIS underground
CAPEX substations	68 073 086,60 CHF	77 017 599,98 CHF	77 017 599,98 CHF
Surface of substations on surface	41000 m2	24794 m2	13011 m2
Volume of substations underground	0 m3	0 m3	89551 m3

But not only the cost and surface of the substation will lead to the optimum, few parameters that will influence this choice:

- OPEX of cables (surface/underground will impact their lengths, so their losses)
- CAPEX of cables (surface/underground will impact their lengths, so their costs)
- OPEX of substations (depending on their technology)
- CAPEX of substations (depending on their technology + cost of the impact on the Civil Engineering)

For more details, presentation on Thursday 13th June at 11:24am “FCC electrical grid and infrastructure: update” by M. Parodi

Optimizing the power control

Beginning of a study in collaboration with the Power Converters group (SY/EPC)

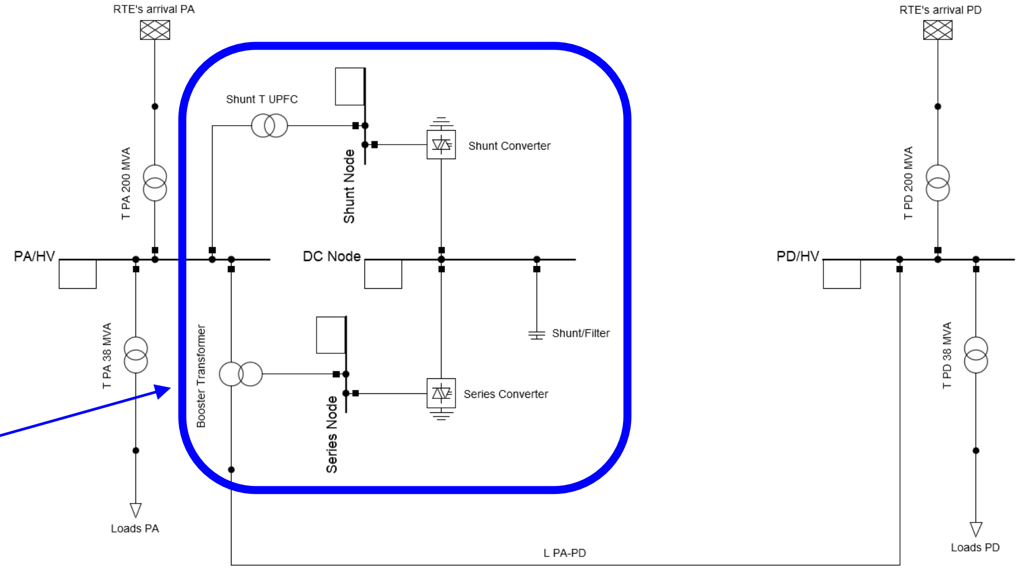
➢ **The goal is to find the most optimal controllers and their location**

Few steps foreseen:

1. Analyzing the loads of FCC (reactive power, THD, etc.) and their location for defining the requirements of the controller
2. Defining the strategy (control of power flows, stability increase and immunity from external disturbances of the network, redundancy, transmission network as closed loop, etc.) and the scenarios of events
3. Simulate different types, settings and locations of control elements with different scenarios
4. Find the most optimal solution of control with regards to CAPEX and OPEX

Example under study: UPFC (Unified Power Flow Controllers)

- Based on Switch-Mode Power Converters (Transistor Technology)
- Series + Parallel Compensation
  - Series: power flow control, voltage drop compensation, voltage dip mitigation
  - Parallel: reactive power compensation / voltage control
- Can be used as energy storage (DC link)



For more details, presentation on Thursday 13th June at 11:42am "DC Networks for the Powering of the FCC" by M. Colmenero Moratalla

Use and storage of renewable energy

The goal is to evaluate the interest of hydrogen use for FCC

Few opportunities foreseen, for energy storage:

- To store renewable energy produced on sites (with solar panels for example) or bought and brought on sites
- For the recovery of energy (for power converters for example)
- For the UPS instead of classic batteries
- For the gensets instead of diesel for powering the backup generators

But also possibilities to investigate for co-generation (or tri-generation) for heating/cooling

Examples where hydrogen is used and comparable to FCC:

- Project EU Stargate and the storage of hydrogen synthesized by electrolysis to raise energy autonomy of airports: powering of vehicles and electrical supply with fuel cells including tri-generation (electricity, heating and cooling)

Evaluate hydrogen's interest at the global FCC system level, balance the benefits/disadvantages of implementing such systems

Conclusion

Few options under investigation to optimize the electrical network, using new technologies, regarding environmental impact, investment cost and operational cost

- **To reduce the space occupation impact:**
  - ➢ Optimizing the cabling in the arc
  - ➢ Optimizing the volumes of the main electrical substations and their locations
- **To optimize the power control:**
  - ➢ Limiting the power losses
  - ➢ Optimizing the sizing of the required equipment
- **To use as much as possible renewable energy:**
  - ➢ Limiting the environmental impact

Studies still need some investigation to establish what is really feasible, the benefits but also disadvantages that come with the proposed solutions

Thanks for your attention.

Many thanks to the FCC Technical Infrastructure WG, the Electricity & Energy Management WP, and the colleagues of EN-EL group, for their contribution.