FCC ELECTRICAL GRID AND INFRASTRUCTURE UPDATE

Acknowledgements to the contributions of the FCC Technical Infrastructure WG, the Electricity & Energy Management WP, and the colleagues of EN-EL group

FCC Week – 13th June 2024

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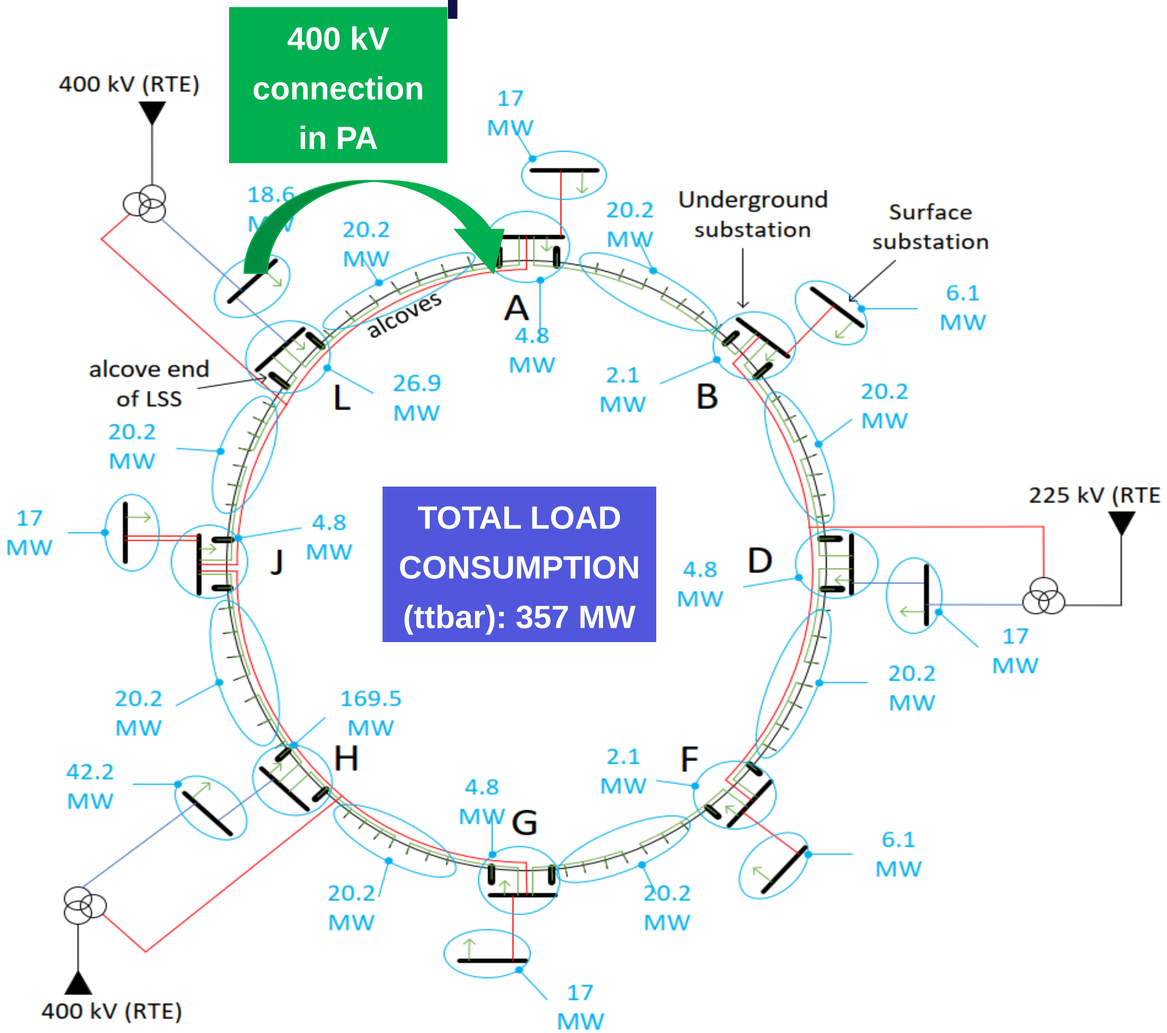
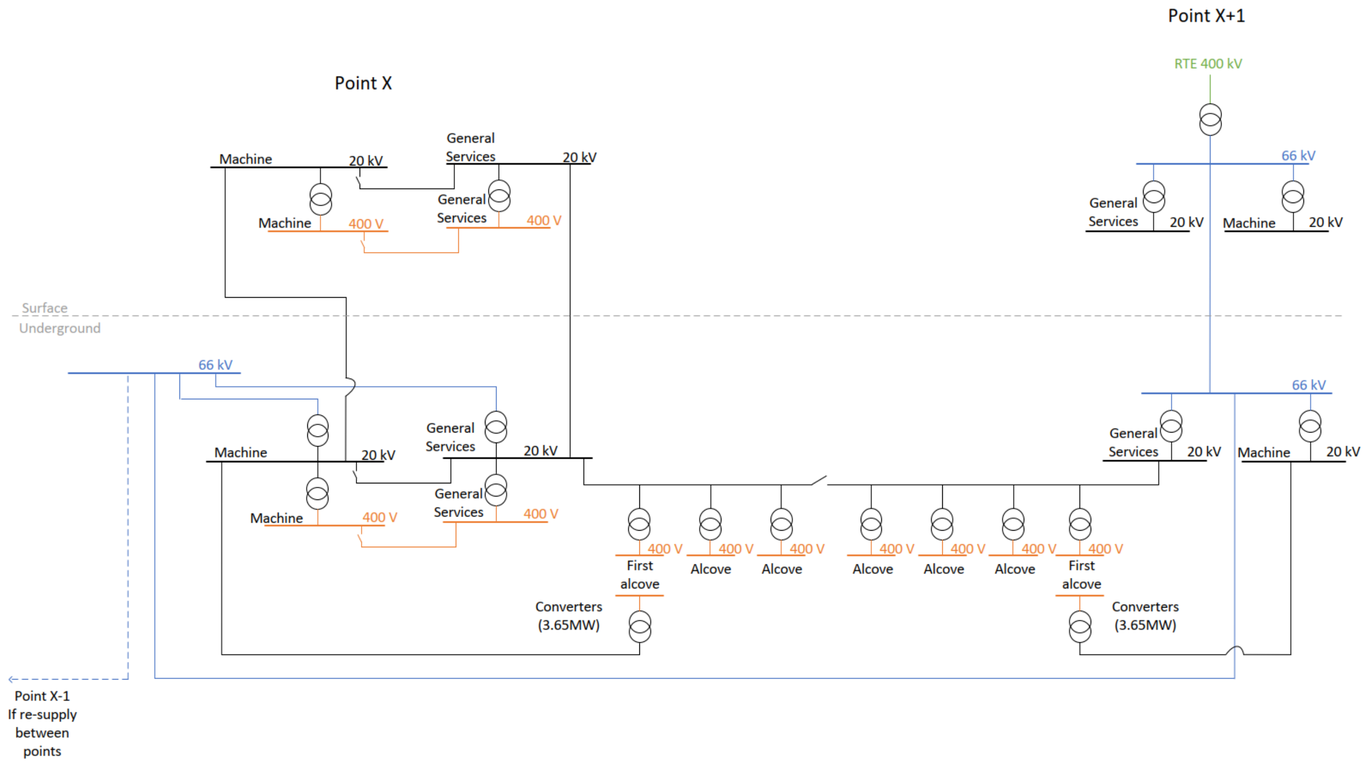
The Future Circular Collider Innovation Study (FCCIS) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 951754.The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.

Status presented at FCC Week 2023





Open points still in 2024:

- **Incertitude of some load forecast (e.g. experiments)**
- **After FCC week, updates expected (e.g. cryo loads)**

Main actions/following steps in 2023:

- Definition of the High Voltage transmission level
- Launch of the feasibility study for the HV cable in the tunnel
- Launch the study of the secured network
- Definition of the main operational scenarios

Voltage level of the HV transmission network

A multi-variable optimization study

- **CAPEX**

→ Cost of supply and installation of Substations
→ Cost of supply and installation of Lines

- **OPEX**

→ Cost of Losses
→ Cost of Maintenance

- **Technology, position and impact on civil works**

→ Comparison between AIS or GIS Substations
→ Substation position (surface or underground)
→ Cost of the m^3 (underground civil works)
→ Cost of the m^2 (land acquisition/value of the freed surface)
→ Three voltage level considered: 63 kV, 90 kV, 132 kV

Voltage level of the HV transmission network

Total Life Cycle Cost - Preliminary results (20 years operation)

- The weight of underground civil works on the CAPEX has a huge impact:
  - The choice of an underground GIS HV substation seems not the optimal, despite it is the one at lowest impact on surface.
- The use of GIS on surface represents the best compromise for space reduction and cost optimization.
- At higher voltage levels, the reduction of the OPEX (losses) is not such to compensate the highest CAPEX.
- From this first iteration, the best scenario seems **a grid at 63 kV, with GIS HV substations on surface**.
- The results are preliminary, they will be further analyzed and improved in the next months to be included in the feasibility report.

	63kV			90kV			132kV		
	AIS surface	GIS surface	GIS underground	AIS surface	GIS surface	GIS underground	AIS surface	GIS surface	GIS underground
OPEX cables	2,170,183.49 CHF	2,170,183.49 CHF	1,996,568.81 CHF	1,391,352.70 CHF	1,391,352.70 CHF	1,280,044.49 CHF	1,146,241.16 CHF	1,146,241.16 CHF	1,054,541.87 CHF
CAPEX cables	28,229,874.18 CHF	28,229,874.18 CHF	26,332,946.18 CHF	28,845,426.18 CHF	28,845,426.18 CHF	26,920,898.18 CHF	30,273,426.18 CHF	30,273,426.18 CHF	28,234,658.18 CHF
OPEX substations	23,438,857.26 CHF	17,525,999.94 CHF	17,525,999.94 CHF	25,716,222.21 CHF	18,802,100.77 CHF	18,802,100.77 CHF	26,311,429.20 CHF	20,969,548.35 CHF	20,969,548.35 CHF
CAPEX substations	273,073,086.60 CHF	200,989,499.98 CHF	309,982,064.98 CHF	289,702,667.64 CHF	227,265,733.89 CHF	378,578,240.65 CHF	302,260,472.00 CHF	272,816,635.45 CHF	503,441,635.45 CHF
TOTAL	**326,912,001.53 CHF**	**248,915,557.59 CHF**	**355,837,579.91 CHF**	**345,655,668.73 CHF**	**276,304,613.54 CHF**	**425,581,284.09 CHF**	**359,991,568.55 CHF**	**325,205,851.14 CHF**	**553,700,383.85 CHF**

HV cable sizing and feasibility report

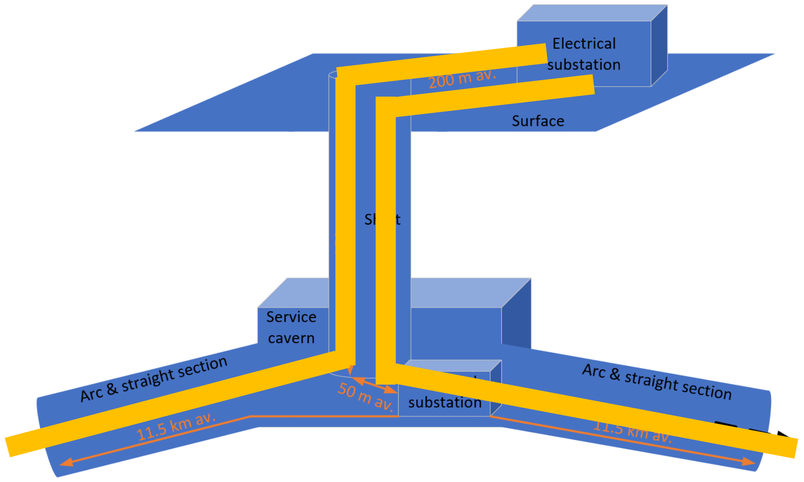
HV grid in the underground

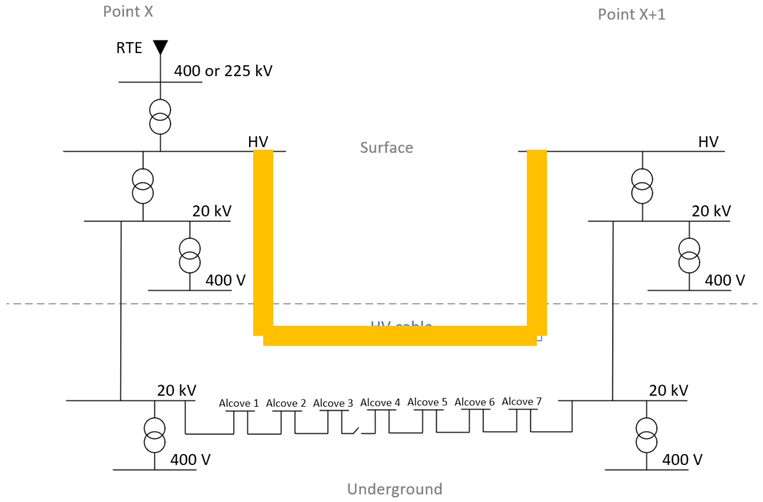
- **Target**: confirm the possibility to install a HV cable to connect two consecutive points of FCC through the underground facilities (pits/caverns/tunnel)
- **Two options** studied

→ 132 kV cable
→ 63 kV cable
→ the option of 90 kV has been analyzed through extrapolations

- Sizing power of each cable: **115 MVA**

→ Compliant with n-1 simulations (see next slides)
→ In accordance with FCC-hh latest forecast (see next slides)

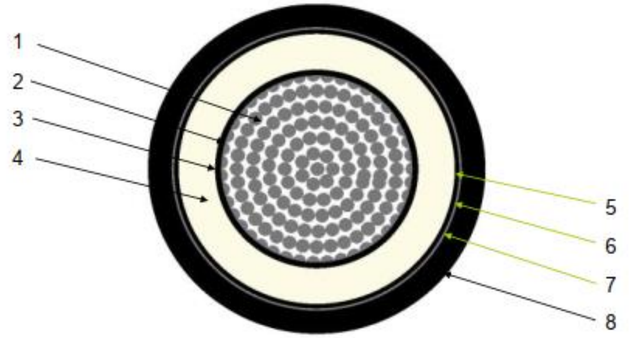




Prysmian Group — Fiche Technique Commerciale — MI

Câble 1200 mm² AL 63 kV PEA - GSC

Voltage	Isolation	Ecran	Icc
36 / 63 / 72.5 (kV)	PR	ALU	8 kA-0,5s



Item	Description	Ep. Nominale (mm)	Détails	Diam. (2) Fabrication (mm)
1	Conducteur	-	Rond aluminium	*41.5*
2	Rubanage	-	Ruban semi-conducteur	--
3	Ecran SC interne	1.3	Polymère semi-conducteur	--
4	Isolation	7.8	PR	*64*
5	Ecran SC externe	1	Polymère semi-conducteur	--
6	Rubannage	-	Ruban S-C hygroscopique	--
7	Gaine métallique	0.5	Ruban Al posé en long à recouvrement et contrecollé	--
8	Gaine extérieure (1)	5	PE + GSC	*79*
			Masse linéique indicative (kg/m) :	*7.3*

Effort de tirage maximal	4320 kg
Rayon de courbure pendant le tirage	3.16 m
Rayon de courbure en installation fixe	1.58 m

(1) Gaine extérieure (PE) avec une couche de semi-conducteur extrudé (GSC)

HV cable sizing and feasibility report

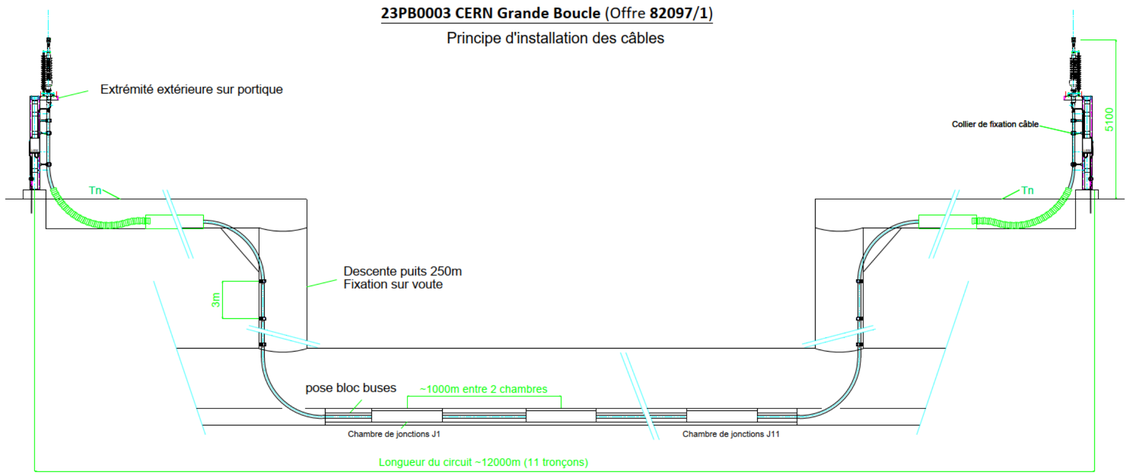
Preliminary results

- **The feasibility is confirmed**, but with **important requirements** to be discussed and agreed with the civil engineering.
- The main points identified so far (very similar for 63 kV and 132 kV):

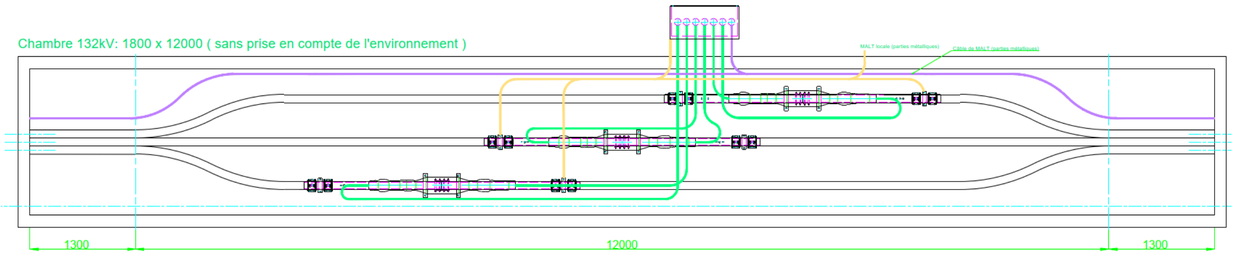
→ Cables with **~3 m of bending radius**: for entrance of pit, entrance of tunnel, and other bends, a suitable cable routing in the civil works must be studied

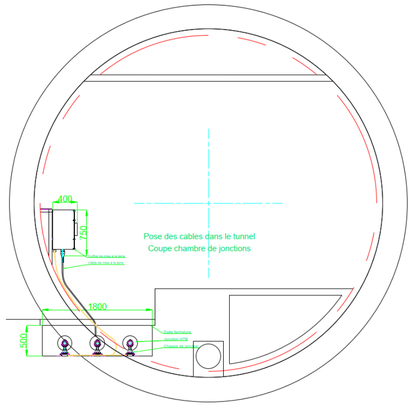
→ **Pulling chambers** each 1 up to 1.5 km for maximum length of the drum and for cross bonding (opportunity: **in correspondence of the alcoves**)

→ **One duct** dedicated to this cables in the floor of the tunnel (two options: filled of concrete or with cable clamps)

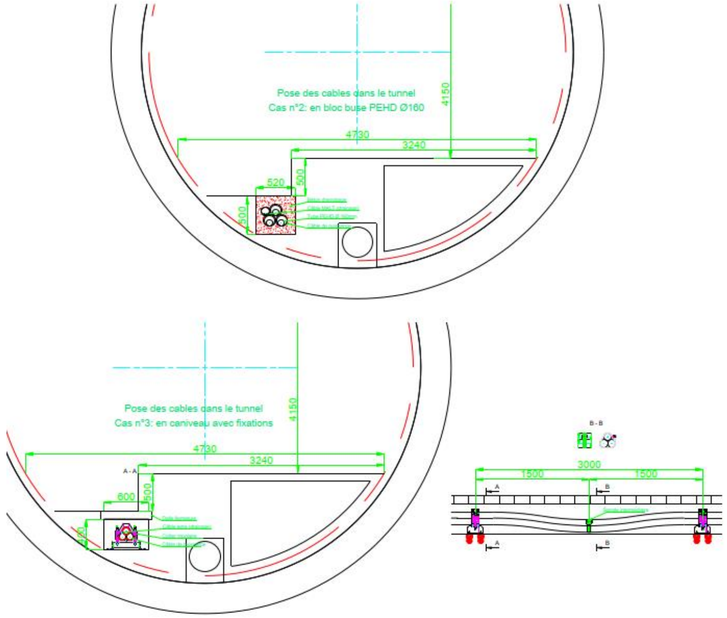


General scheme P(n) - P(n+1), **cable with 3 m of bending radius**



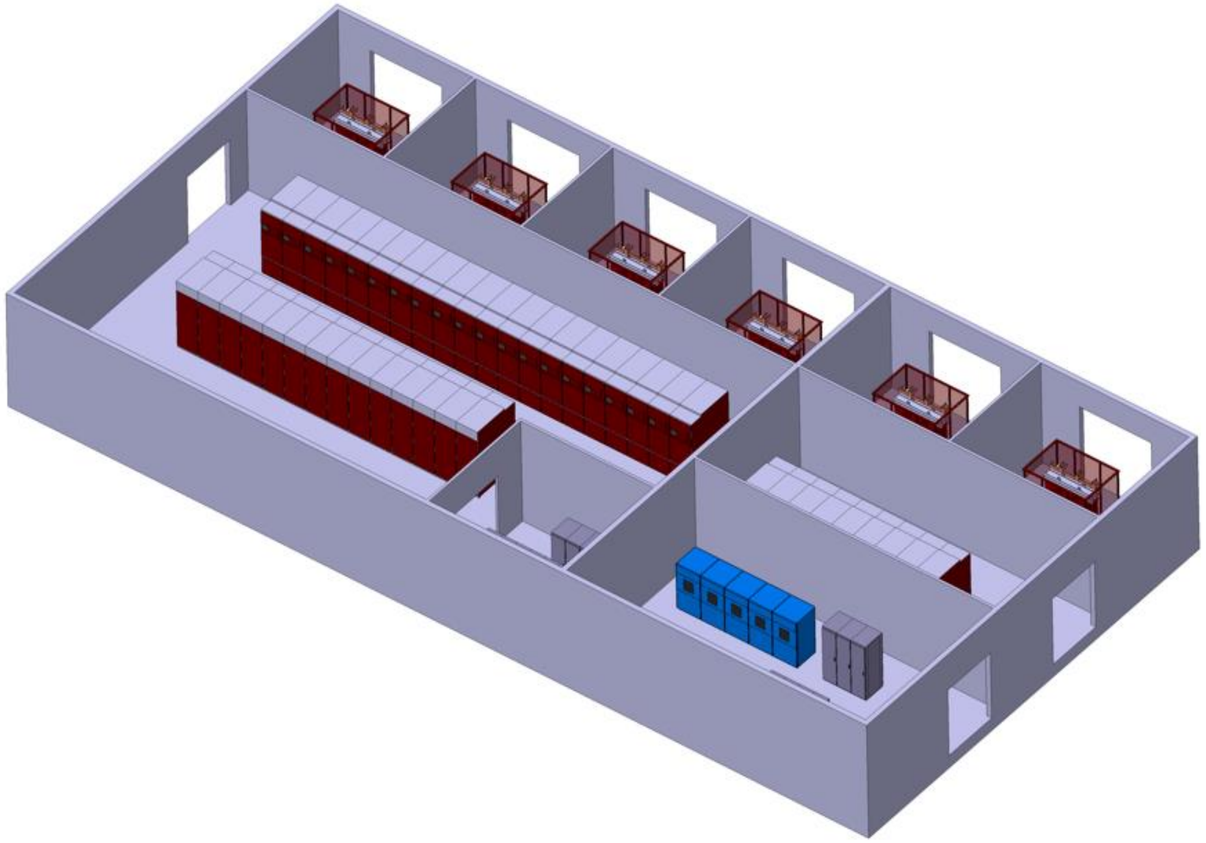


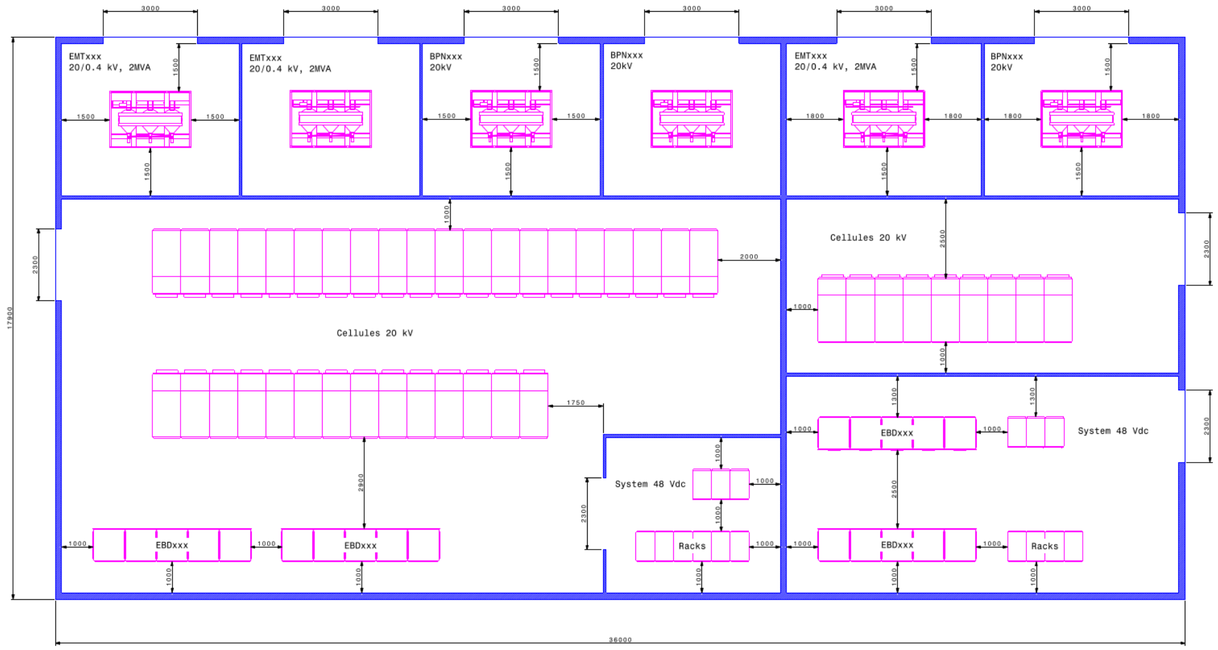
Puling chamber (**15 m x 1.8 m, each 1000…1500 m in the tunnel**)



Tunnel cross section with **a duct for the HV cables**

MV/LV Substations





The core of surface and underground power supply

- Two main MV/LV substations per point

→ One in **surface** (building)

→ One in **underground** (service cavern and tunnels)

- Split between **process (machine) and general services**
- Exception: one only network going into alcoves for general services and power converters

→ **Optimized solution**: one line instead of two for each sector

- Preliminary study of the building, approx. **18x36** m.
- **The required space in the service caverns and tunnels will be similar:** important input for the integration study.

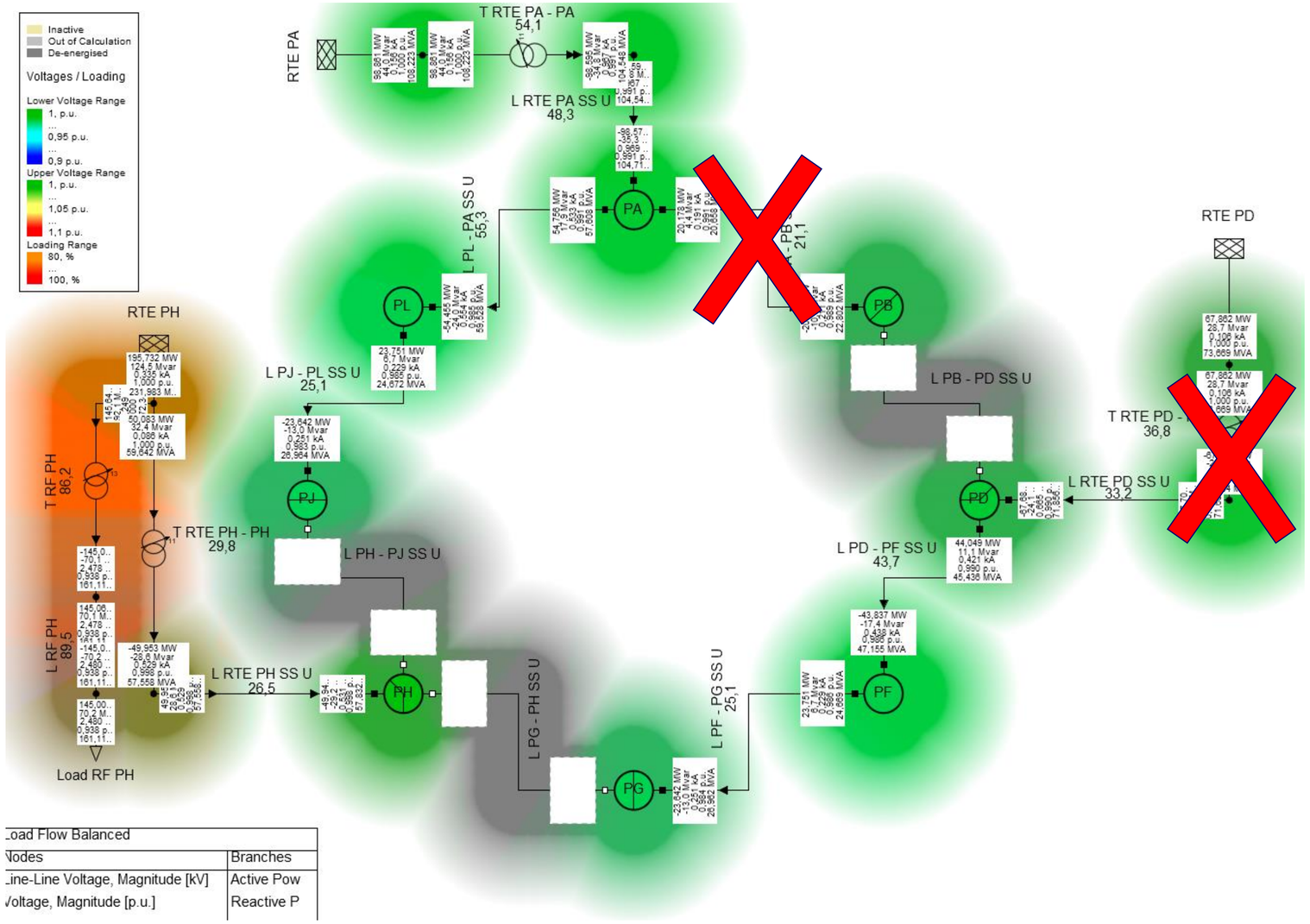
Operational scenarios: nominal and degraded modes

HV grid (reminder)

- If the HV source of **PH** is lost : **FCC-ee cannot operate**
- If any other source (PA & PD) or one HV line in the tunnel is lost : **the network can be reconfigured to operate:**

→ Loss of RTE PA
→ Loss of RTE PD
→ Loss of PA-PB
→ Loss of PD-PF
→ Loss of PF-PG
→ Loss of PJ-PL
→ Loss of PL-PA

- For this purpose (and for FCC-hh forecast) the dimensioning power of the cables has been set at 115 MVA.



Operational scenarios: nominal and degraded modes

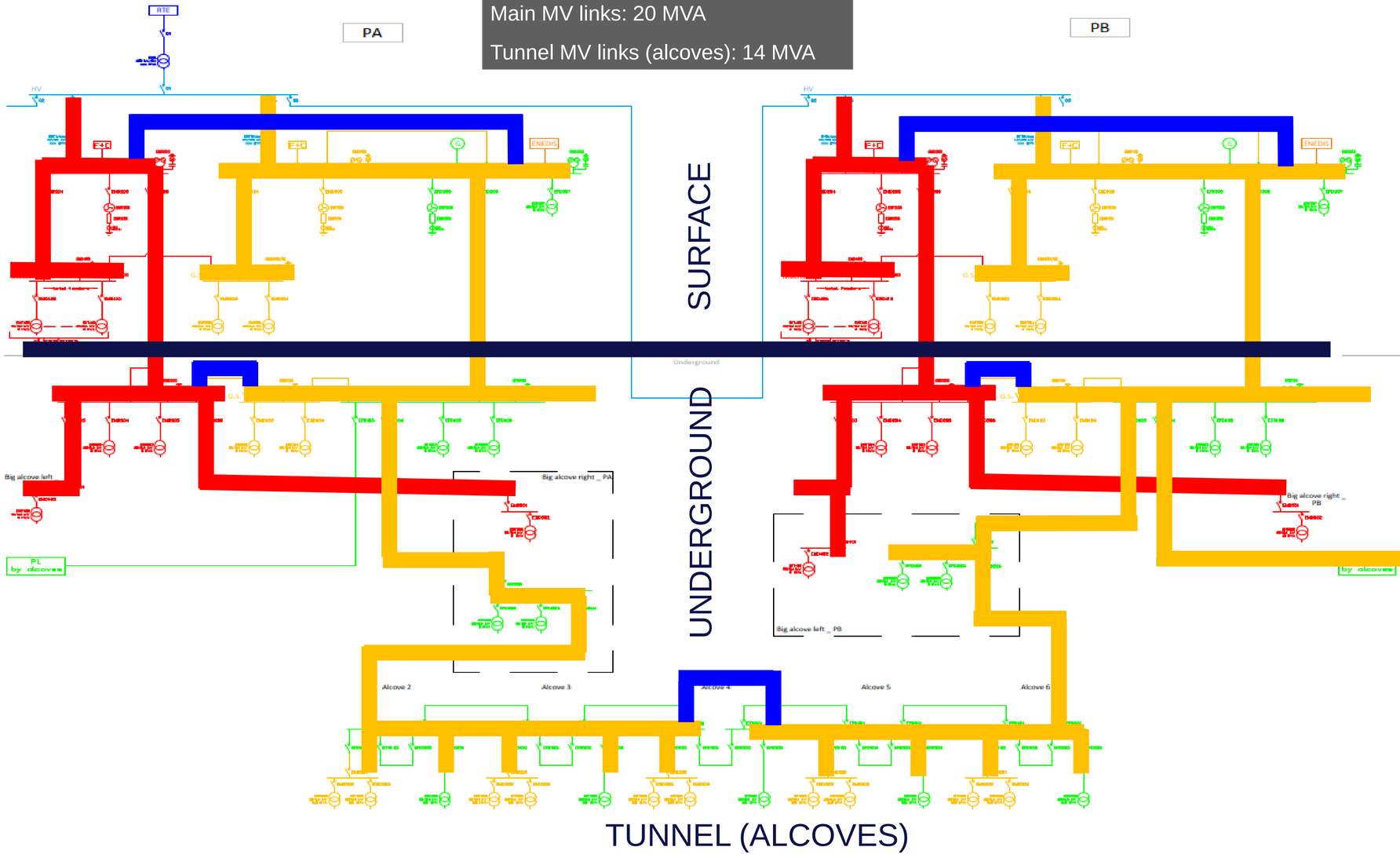
HV/MV transformers: 40 MVA

Main MV links: 20 MVA

Tunnel MV links (alcoves): 14 MVA

Optimized resilience and maintainability of the MV network

- Nominal mode: two MV networks for each point **(machine and general services**). Each point supplies **half sector**.
- For each point: Possible **mutual re-supply in surface**.
- For each point: Possible **mutual re-supply in surface**.
- Possible re-supply of the **full sector from one point**.
- Some backup configurations can be targeted for the **full load during Run**; it will depend on the load conditions and the power quality.
- Automatic system re-configuring the network based on the status. Not only failure, but also **efficiency** can be set as an objective for its actions.



Secured/Backed-up network

Rating of sources **not yet defined**:
- All users need to identify the **safety-related loads**
- List to be validated by the safety assessment of FCC-ee
- **The electrical secured network must be considered a safety system**

Optimized infrastructure for safety

- MV power supply (20 kV)
- **Two backups** per point:

→ Gensets

→ Local public utility (the one for worksites)

- **Same links for normal and secured networks**

→ Load-shedding

- High maintainability

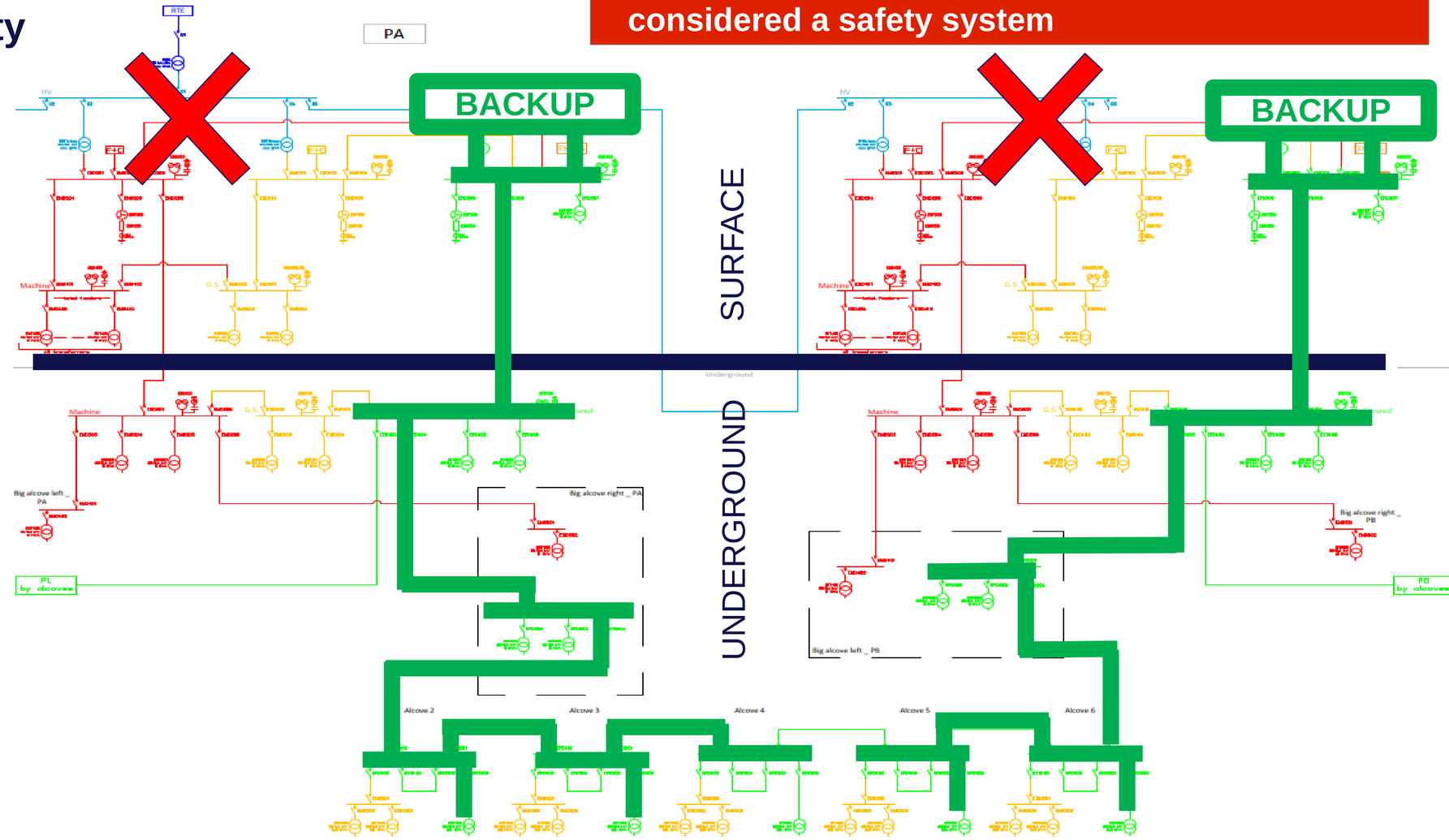
→ **Two networks arriving in all the alcoves** (from the two points)

→ Possibility to **re-supply from the adjacent poin**t in case of maintenance or major fault on the sources

- Challenge:

→ Fire-resistance of MV infrastructure

→ Opportunity: protection through the civil works (ducts)



400 kV supply from CERN BE2 substation

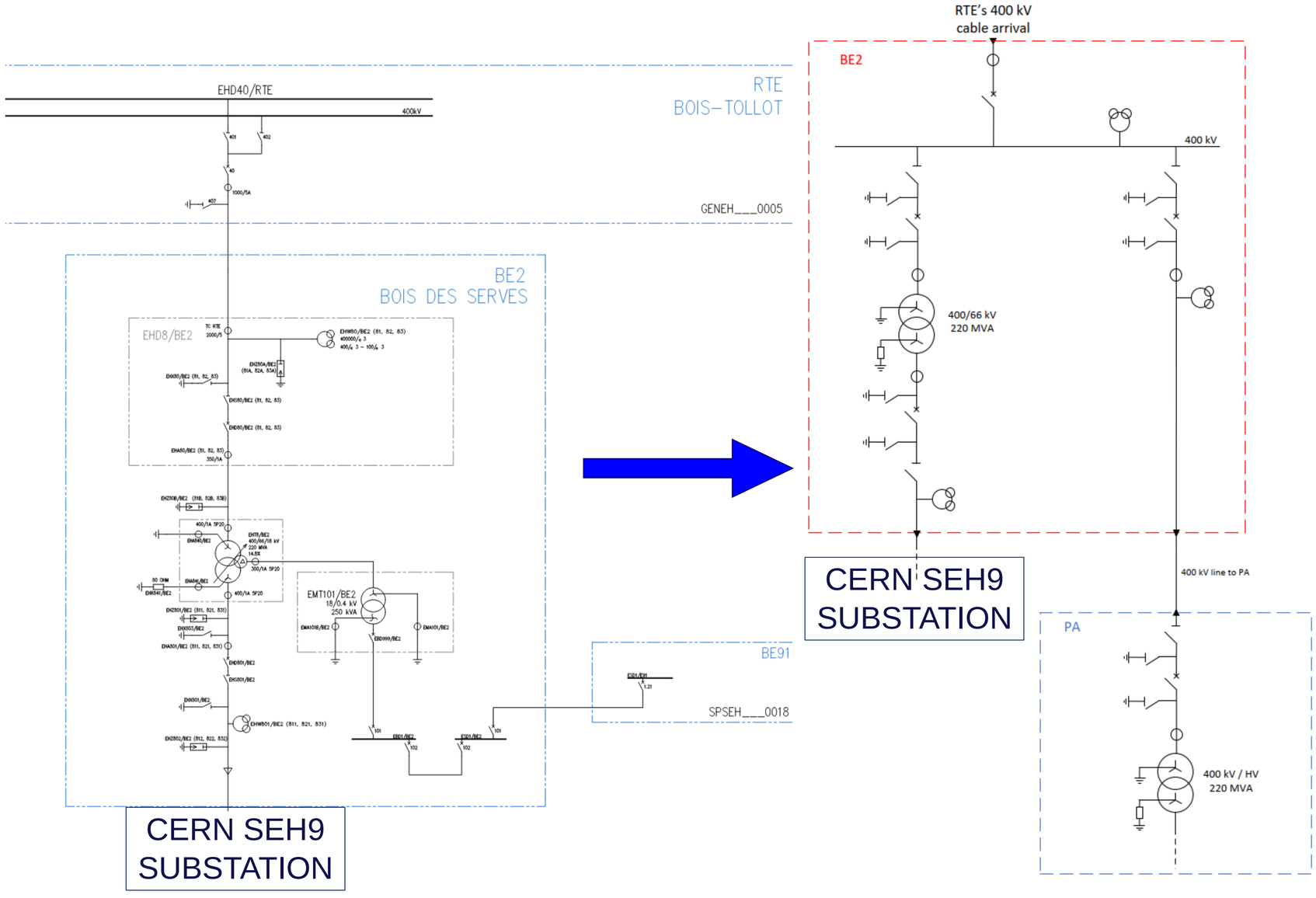
Decision 2023: move one HV connection from PL to PA

- Reason: existing 400 kV connection from RTE Bois-Tollot substation to CERN; PA close to LHC8
- Proposal:

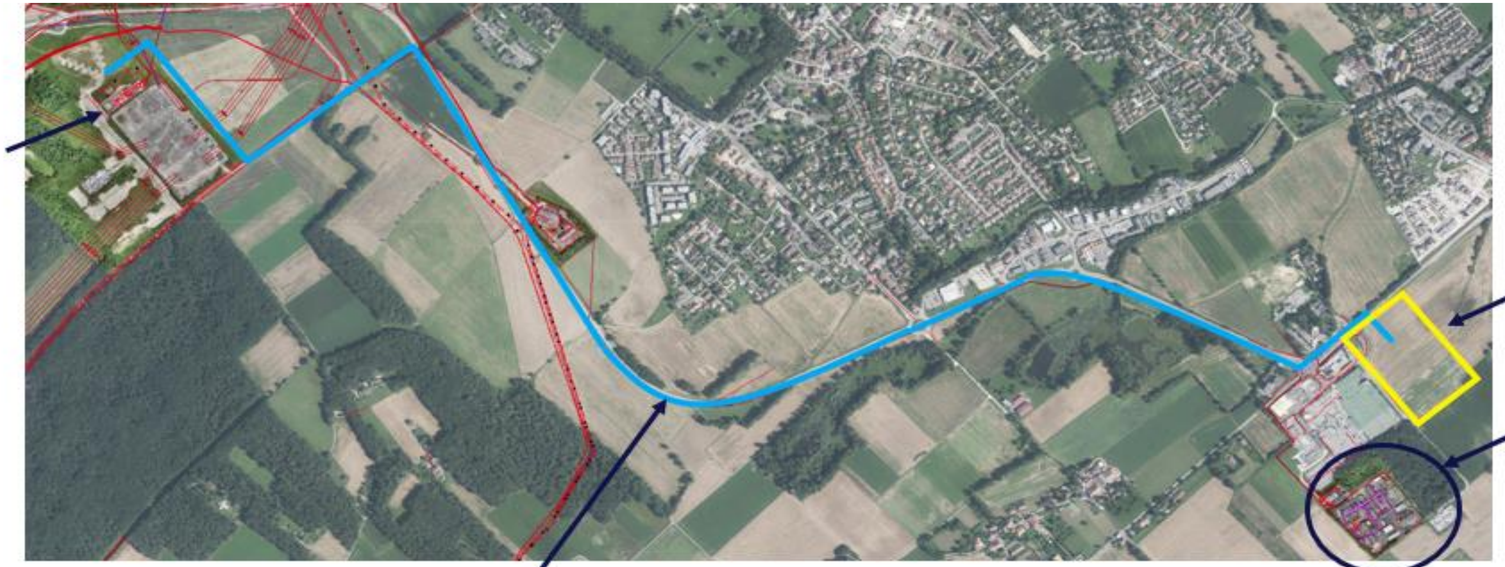
→ To add a new 400 kV bay at **BE2 CERN substation** (commissioned in 2019)

→ To create a **400 kV line from BE2 to PA** (approx. 4.5 km)

- To create a substation 400 kV at PA instead of PL
- The extension of BE2 substation is confirmed **feasible**



400 kV supply from CERN BE2 substation



PRELIMINARY IDENTIFICATION OF A POSSIBLE TRACK

Possible constraints to be considered:

- Definition of the track Vs. land acquisition process.
- **Environmental impact**:

→ A trench for a 220 MVA 400 kV buried cable has a not negligeable width and depth.

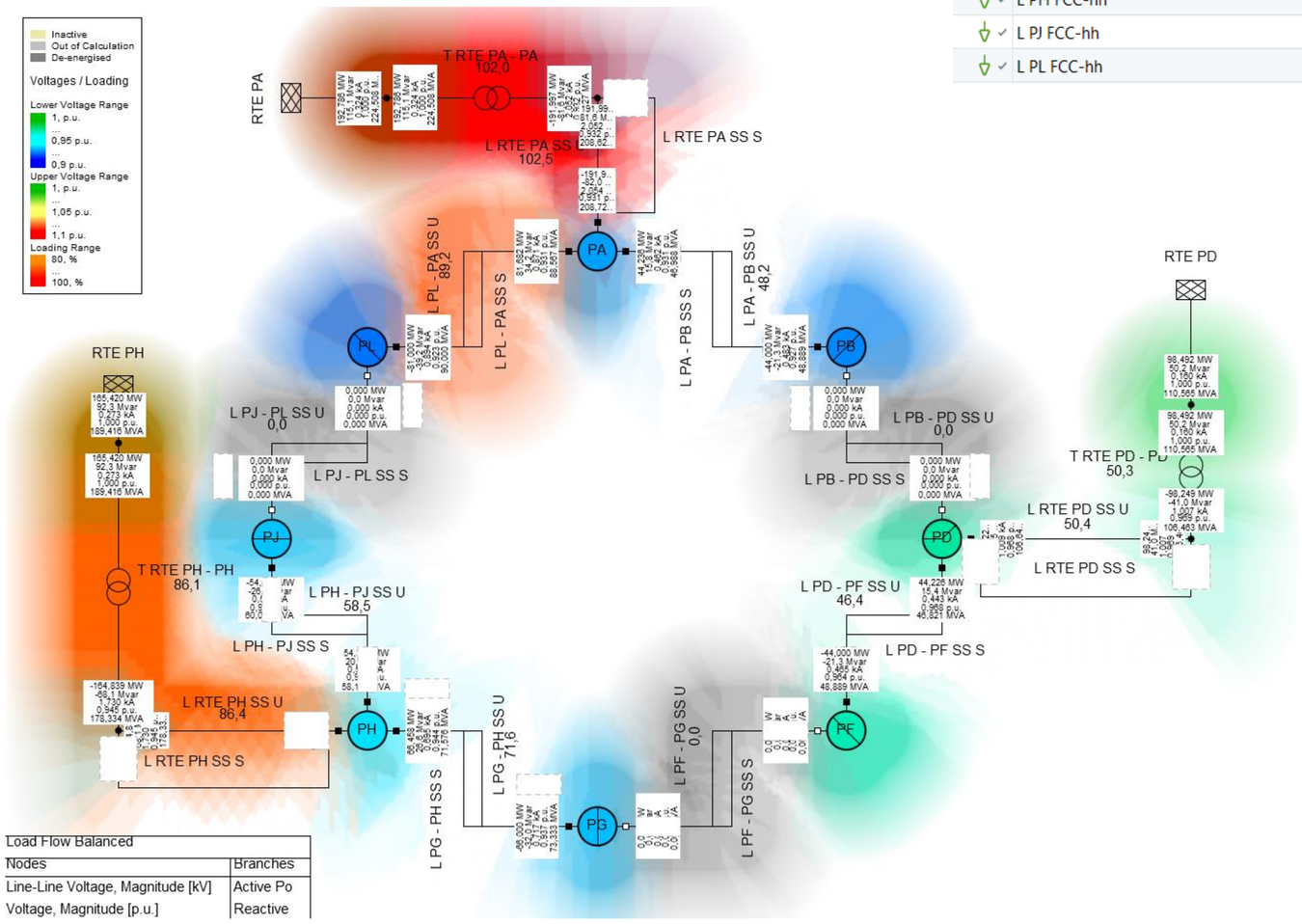
- Specific rules and regulations for 400 kV lines (process mastered by RTE in France).
- **Long planning and process for approval and execution**, approximately 10 years once the first proposal is submitted.

→ Anyway **similar timelines are given by RTE for the other two points**.

- Possible alternative: ask RTE to extend Bois-Tollot substation and pull a new line to PA from there (full outsourcing to RTE as per the other two points).

Projection towards FCC-hh

Name	In Folder	Grid	Input Mode	Local Controller	Balanced/Unbalanc...	Act.Pow. MW
L PA FCC-hh	PA	HV Grid FCC-hh - 63 kV	PC	constq	0	66,
L PB FCC-hh	PB	HV Grid FCC-hh - 63 kV	PC	constq	0	44,
L PD FCC-hh	PD	HV Grid FCC-hh - 63 kV	PC	constq	0	54,
L PF FCC-hh	PF	HV Grid FCC-hh - 63 kV	PC	constq	0	44,
L PG FCC-hh	PG	HV Grid FCC-hh - 63 kV	PC	constq	0	66,
L PH FCC-hh	PH	HV Grid FCC-hh - 63 kV	PC	constq	0	44,
L PJ FCC-hh	PJ	HV Grid FCC-hh - 63 kV	PC	constq	0	54,
L PL FCC-hh	PL	HV Grid FCC-hh - 63 kV	PC	constq	0	81,



HV grid of FCC-ee still suitable for FCC-hh

- Latest forecast: total power of **453 MW** during Run.
- The HV sources and transmission grid **can cope with the load requirements**.
- Nevertheless, the sizing of some sources and lines reached its **maximum capability** during Run with the latest load distribution.
- In degraded mode (machine STOP, cryo ON) the grid allows the **re-supply of the critical loads**, essential during maintenance or major faults
- **No studies performed for FCC-hh after the CDR of 2018**. The projection comes from the load flow with the latest requirements received, using the grid of FCC-ee.
- **No analysis have been performed on the downstream grid** (MV, LV). The localisation and layout of the loads is not known.

Conclusions and next steps

- **Takeaway messages:**

→ The **optimization** of the voltage level of the HV grid and the position of the substations **is converging** and must be concluded.

→ The feasibility of the installation of a HV cable in the tunnel **is confirmed as a principle**, adding **important requirements to the integration and the civil engineering**.

→ The MV/LV substations have been studied: first layout proposed for **surface building**, similar requirements will be included in the integration study of the **service caverns/tunnels**.

→ For the **secured network**, the principle has been studied; **a list of safety-related loads must be defined** to allow the sizing of the network.

→ The detailed load forecast for FCC-ee Is not yet completed and still evolving: **the results presented are still preliminary**.

→ Based on the latest received load forecast and distribution, **the HV grid of FCC-ee is still usable for FCC-hh**, approaching its limits in some points.

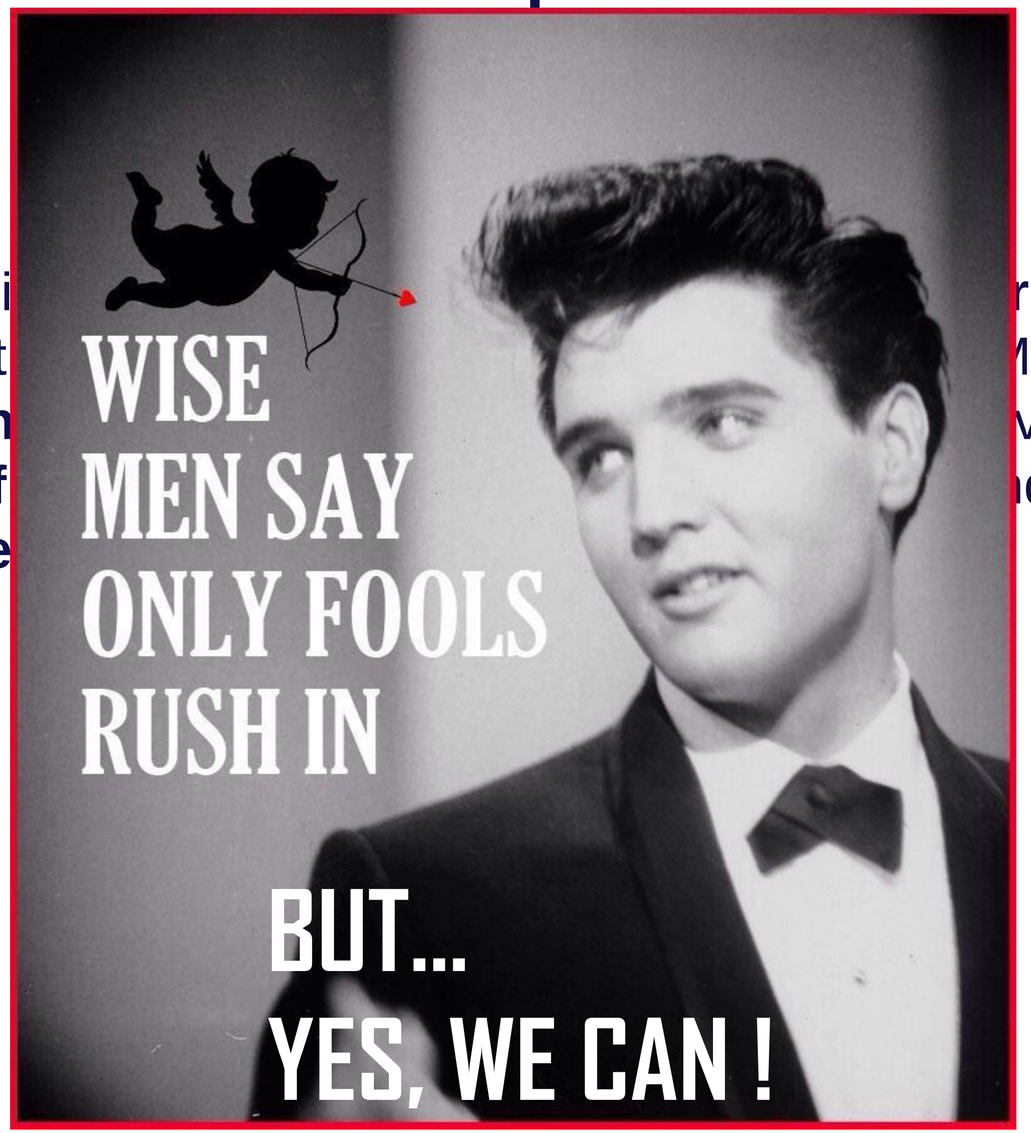
Conclusions and next steps

- **Other next steps:**

→ Based on the previous poi**r the integration** (including also services and cable st**Marcel).**

→ **Finalize the optimization**vices under studies for the **network stability and eff**nd M. Colmenero Moratalla).

→ Update the **cost estimate**



SOME THINGS ARE MEANT TO BE !

Thanks for your attention

Backup Slides

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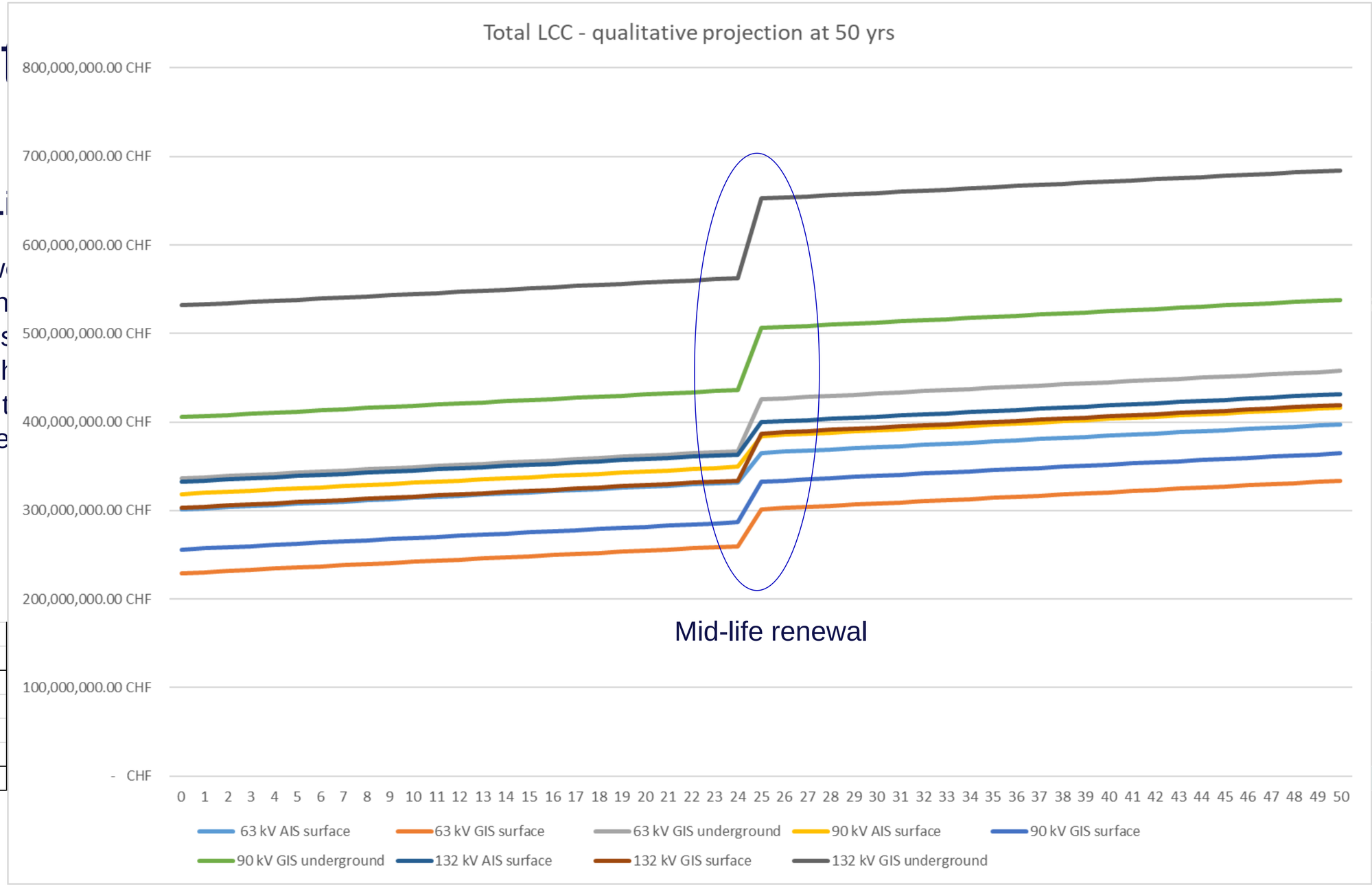

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