FUTURE CIRCULAR COLLIDER

ELECTRICAL DISTRIBUTION CONCEPT AND LAYOUT

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FCC week 2023

Content

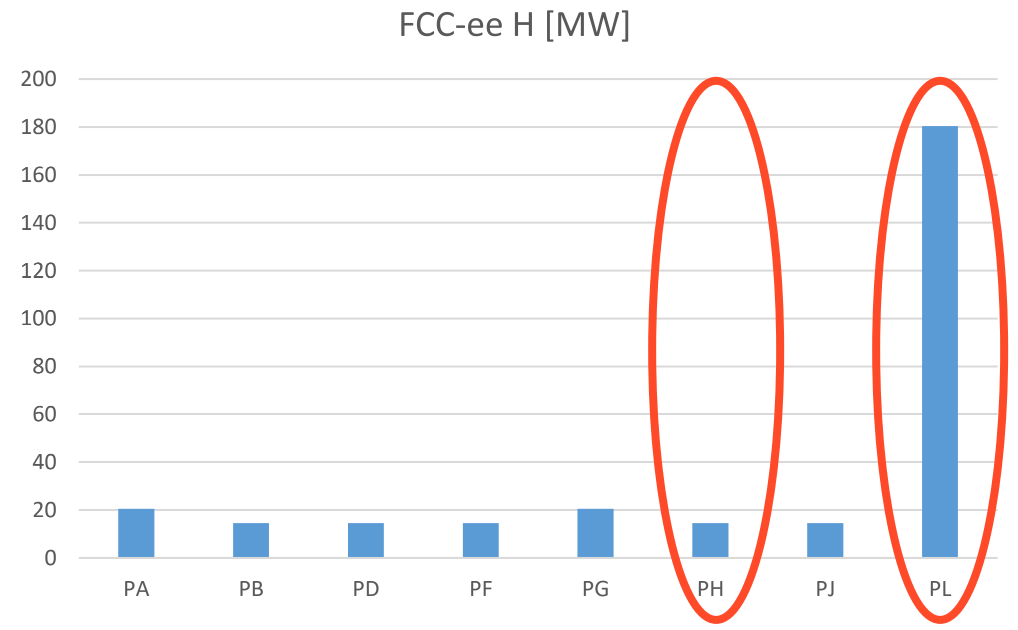
Baseline presented at FCC week 2022

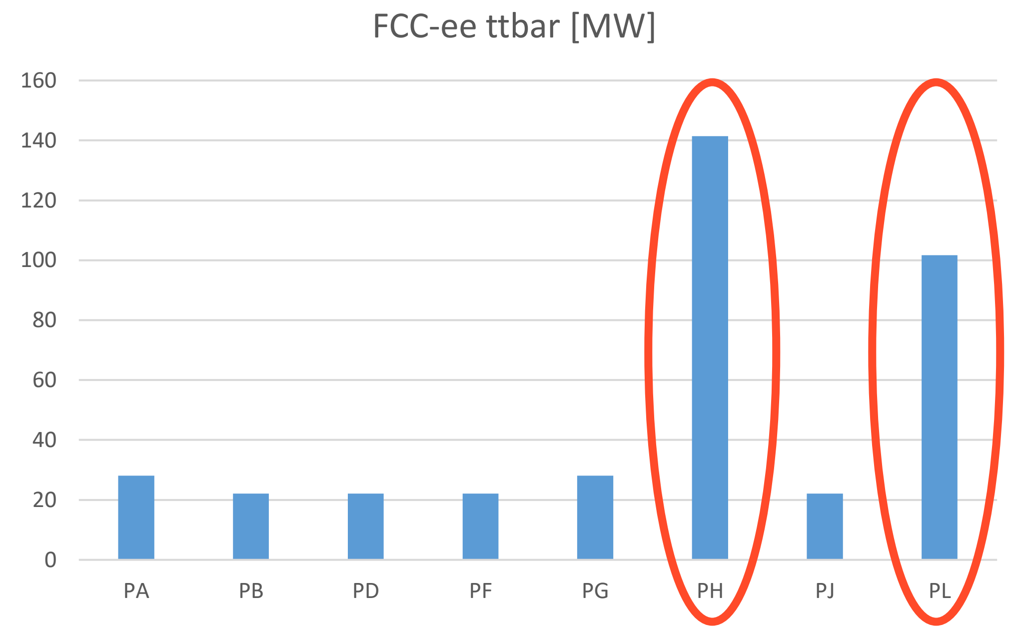
Highly unbalanced load request:
- Radio Frequency systems at points H and L
- Unbalance between phases of the machine

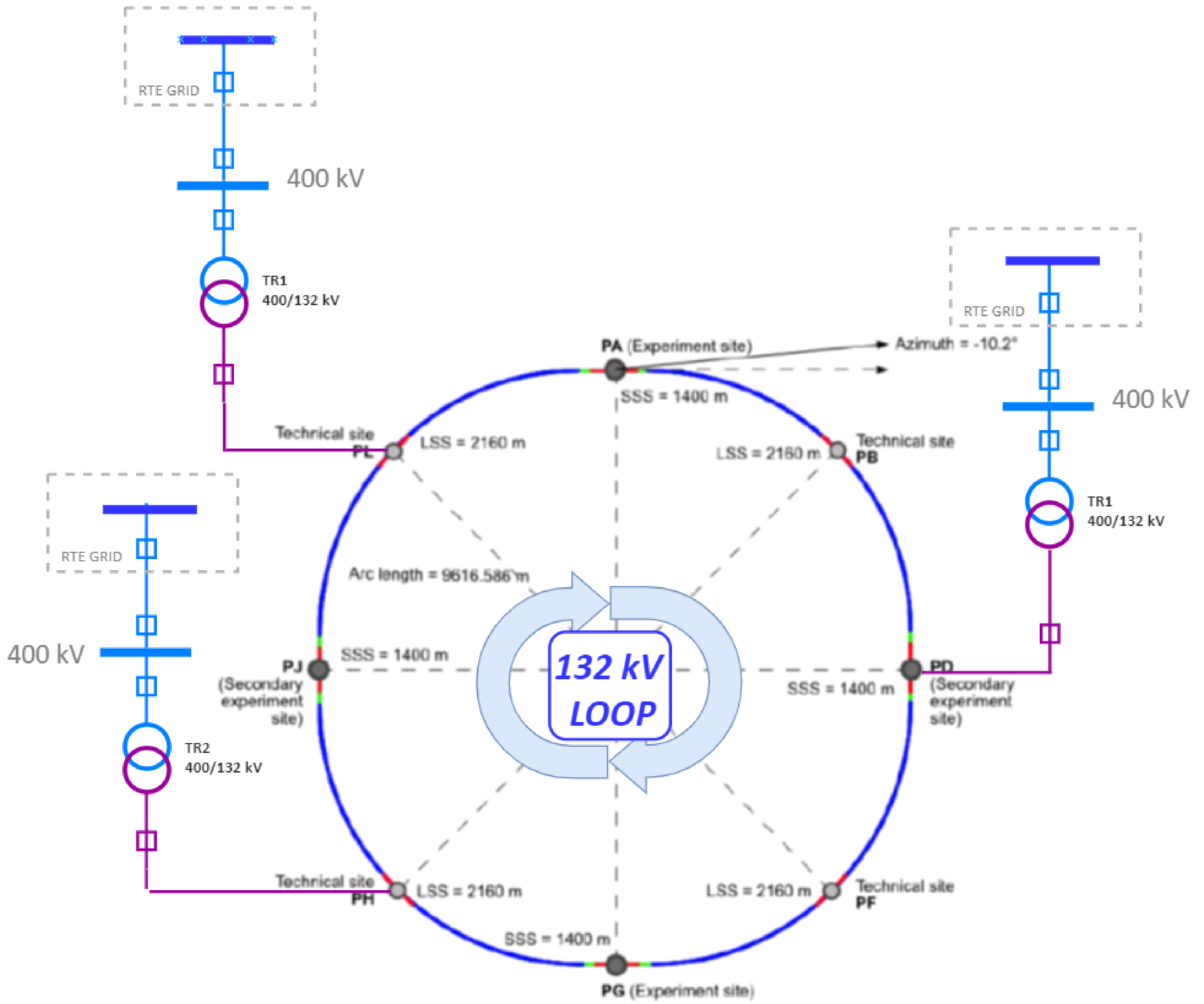
3 Connection points to RTE grid (PD, PH, PL)
Internal 132 kV transmission loop
All points would have a 132/36 kV substation

Electrical power	Z [MW]	W [MW]	H [MW]	ttbar [MW]
Radio Frequency	148	148	148	148
Cryogenics	1	7	17	51
Cooling and Ventilation	33	34	36	40
Magnets	7	20	44	100
Experiments	8	8	8	8
Data centers	4	4	4	4
General services	36	36	36	36
Total	**237**	**257**	**293**	**387**

Split	P [MW]	P [MW]	P [MW]	P [MW]
PA	16	17	20	28
PB	10	11	14	22
PD	10	11	14	22
PF	10	11	14	22
PG	16	17	20	28
PH	10	11	14	141
PJ	10	11	14	22
PL	159	167	180	102







+ preliminary load flow analysis had been done based on this grid

Update on the load requirements

Main update:
- RF (Radio Frequency system) of the colliders at Point H
- RF of the booster at Point L

Other updates:
- Preliminary load survey done to main users identified:
  - ➢ Cooling & Ventilation (CV)
  - ➢ Cryogenic systems (Cryo)
  - ➢ Transport
- Refinement of the estimation of the loads for General Services:
  - ➢ Lighting, power outlets

Separation of:
- Total required loads for the sizing (as if simultaneity = 1 all the time)
- Loads predicted to be consumed with simultaneity (when details on the consumption already known)
- Locations of loads: at a point on surface, underground, and in an arc between two points

	P_sizing (MW)
RF	184,0
Cryo	44,9
CV	74,1
Magnets	91,8
Vacuum	36,8
Transport	19,4
Experiments	14,0
Data centers	6,0
General services	34,0
Total	505,0

Estimation not supported by any detailed load request

		P_sizing (MW)
PA	surface	17,0
	underground	4,8
PA - PB		20,2
PB	surface	6,1
	underground	2,1
PB - PD		20,2
PD	surface	17,0
	underground	4,8
PD - PF		20,2
PF	surface	6,1
	underground	2,1
PF - PG		20,2
PG	surface	17,0
	underground	4,8
PG - PH		20,2
PH	surface	42,2
	underground	169,5
PH - PJ		20,2
PJ	surface	17,0
	underground	4,8
PJ - PL		20,2
PL	surface	18,6
	underground	26,9
PL - PA		20,2

Example of preliminary estimations

‘Consumed’ loads requirements lower (at maximum should be below 400 MW for the whole machine)

	VACUUM INSTAL P_consumed (MW)	STOP P_consumed (MW)	RUN P_consumed (MW)
TOTAL	74,57	88,64	379,70

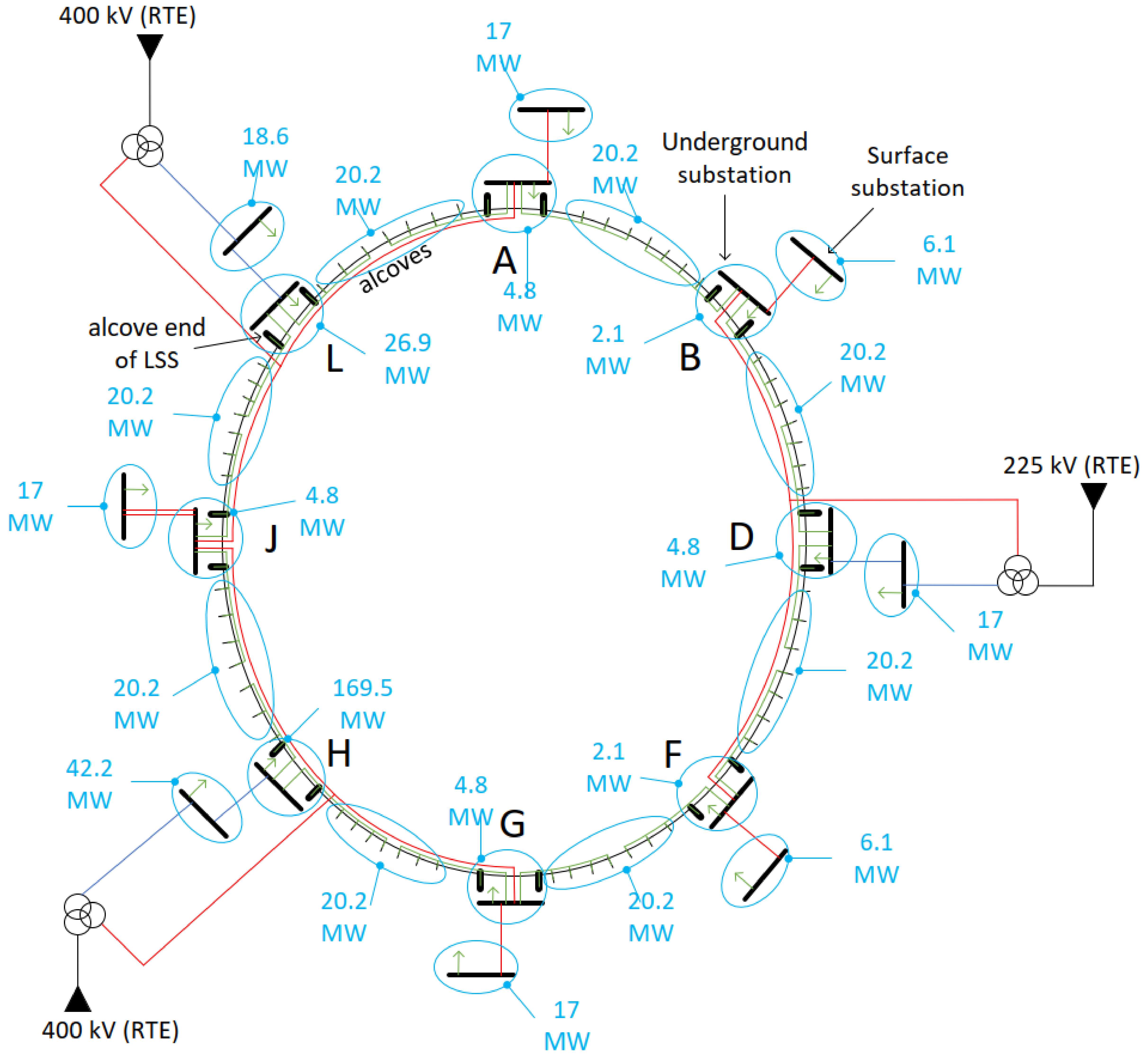
Load mapping of the machine

- Based on users' requests developed by points and facilities where available (underground sectors)
- **Preliminary requirements – updates and modifications are expected**

- Radio Frequency systems at points H (colliders) and L (booster): hot points
- Loads still unbalanced between phases of the machine (Z, W, H, ttbar)

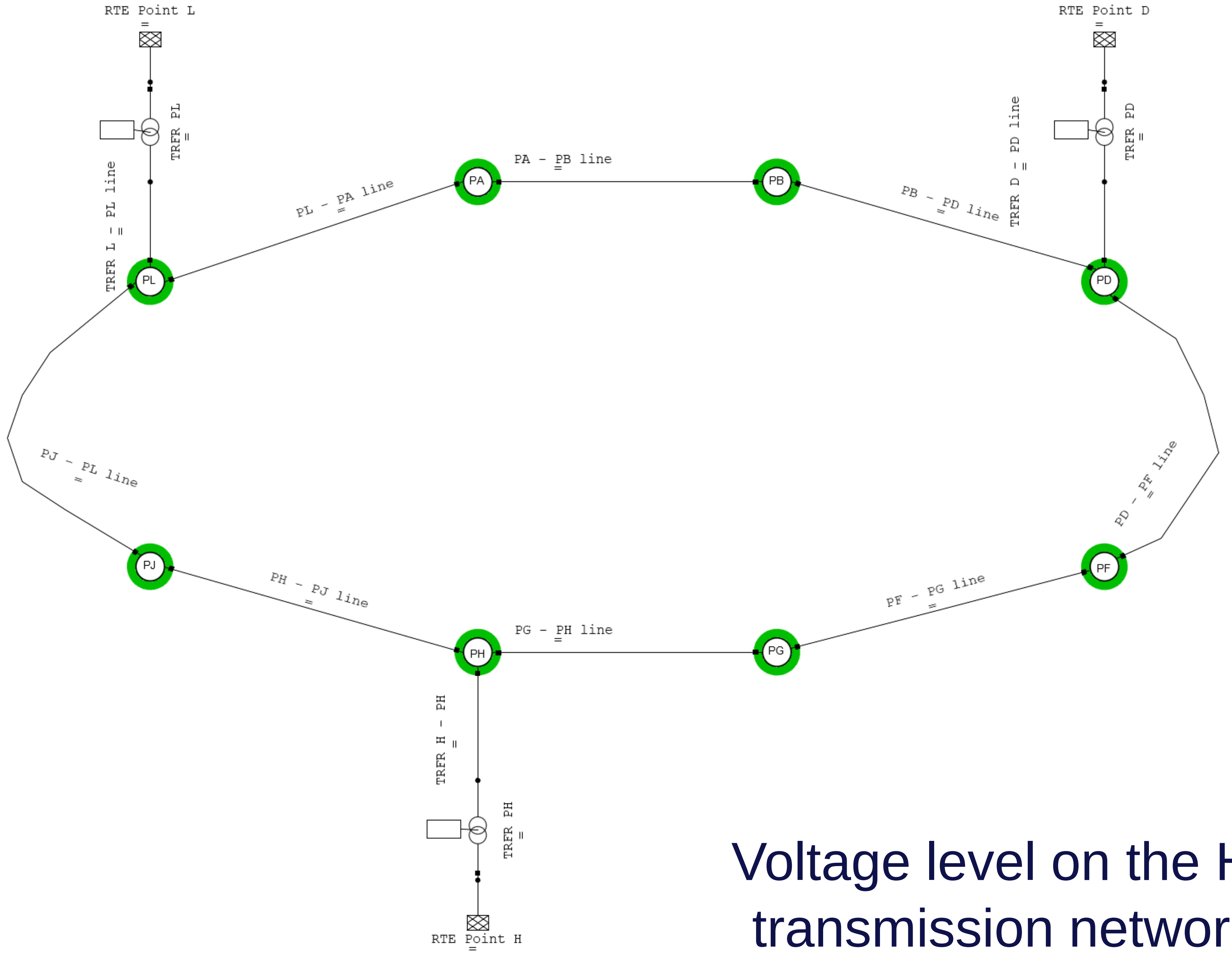
Categorization of loads:

Loads class	Loads type (non-exhaustive list)	Power unavailability duration in case of degraded scenario
Machine	Power converters, RF, cooling pumps, fan motors, etc.	Until return of main supply
General Services	Lighting, outlets	Until return of main or secondary supply
Secured	**Personnel safety** related loads (lighting, pumps, elevators)	10-30 s
Uninterruptable	**Personnel safety** (evacuation and anti-panic lighting, fire-fighting system, oxygen deficiency, evacuation) **Machine safety** (sensitive processing and monitoring, beam loss, beam monitoring, machine protection)	Interruptions not allowed, continuous service mandatory

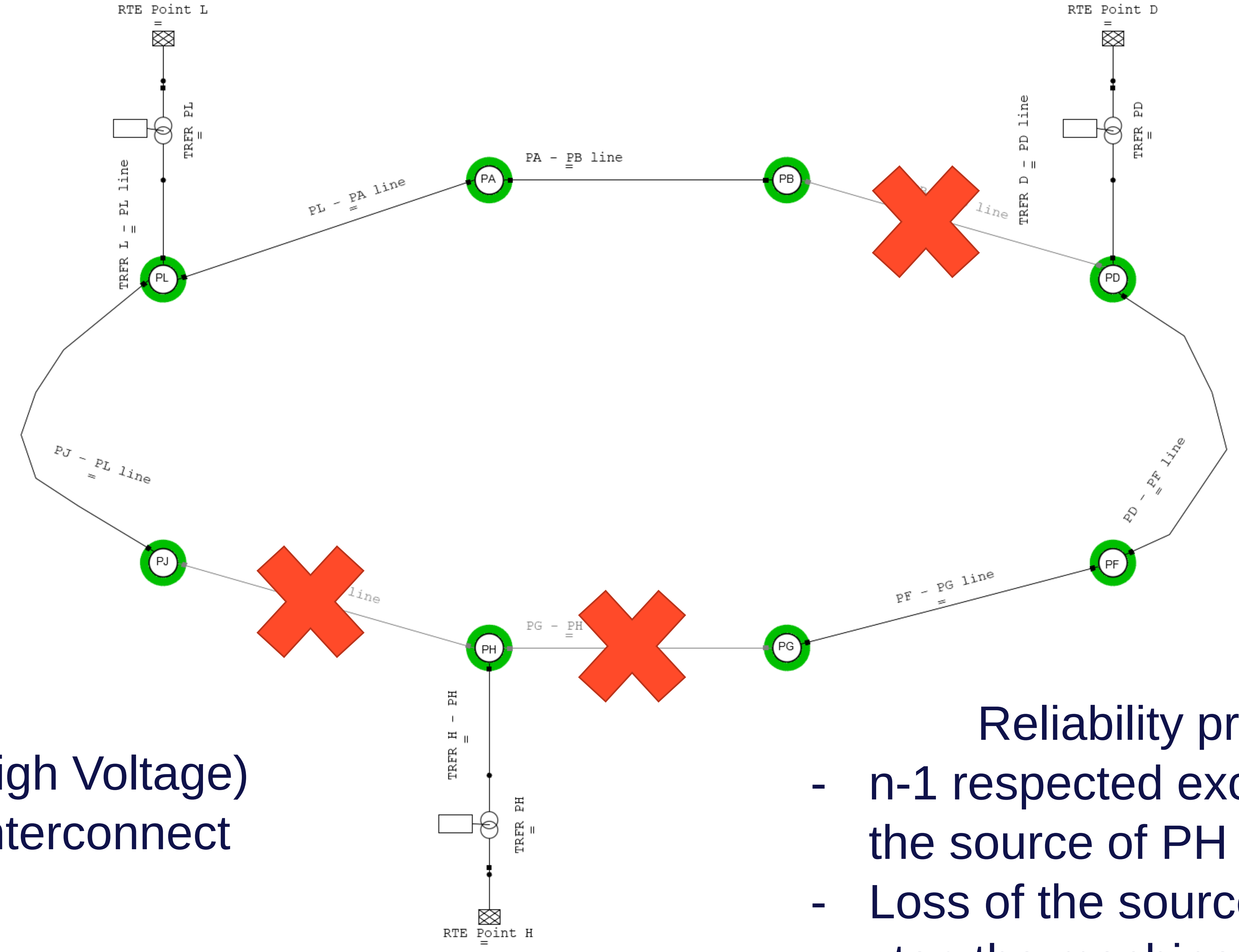


High Voltage network scheme

Closed loop



Open loop



Voltage level on the HV (High Voltage) transmission network to interconnect points ?

Strategy for the location of HV substations ?

Reliability principles:

- n-1 respected except for loss of the source of PH
- Loss of the source of PH will stop the machine
- Cost/benefit analysis to be performed

High Voltage network scheme

Voltage level analysis

3 voltage level studied:
- **132 kV** (baseline from FCC week 2022)
- **66 kV** (currently used at CERN)
- **40 kV** (voltage level asked by converters)

Voltage level	Cables on the loop	Dimensions
132 kV	1x 400 Cu (145kV)	1x (3x81mm diam.)
66 kV	2x 400 Cu (72,5kV)	2x (3x67mm diam.)
40 kV	4x 300 Cu (72,5kV)	4x (3x64mm diam.)

Branch losses & Line charging

Optimization of the power lines characteristics (to have them up to 75% of charge)

Optimization made on 3 parameters:
- Capex (price of cables, cable trays, installation)
- Opex (price of operation, electrical losses)
- Space occupation

Cost/benefit analysis ongoing to select the best voltage level

This choice will also impact the location of the HV substation (underground or surface)

Preliminary results:
- The higher the voltage, the smaller the losses, and the lower the voltage, the more cables in parallel needed
- **But** the higher the voltage, the more expensive the prices of equipment and the space occupation of substations Also, the line charging current increases with the voltage, but it does not seem to be a critical parameter provided that the voltage regulation strategy will follow it (not yet analyzed)
- From a space occupation point of view, the 40 kV seems not applicable for the overall transmission network

(For the real sizing: use of standard voltage levels)

High Voltage network scheme

Underground High Voltage network scheme

Solution in investigation: underground HV/MV substations

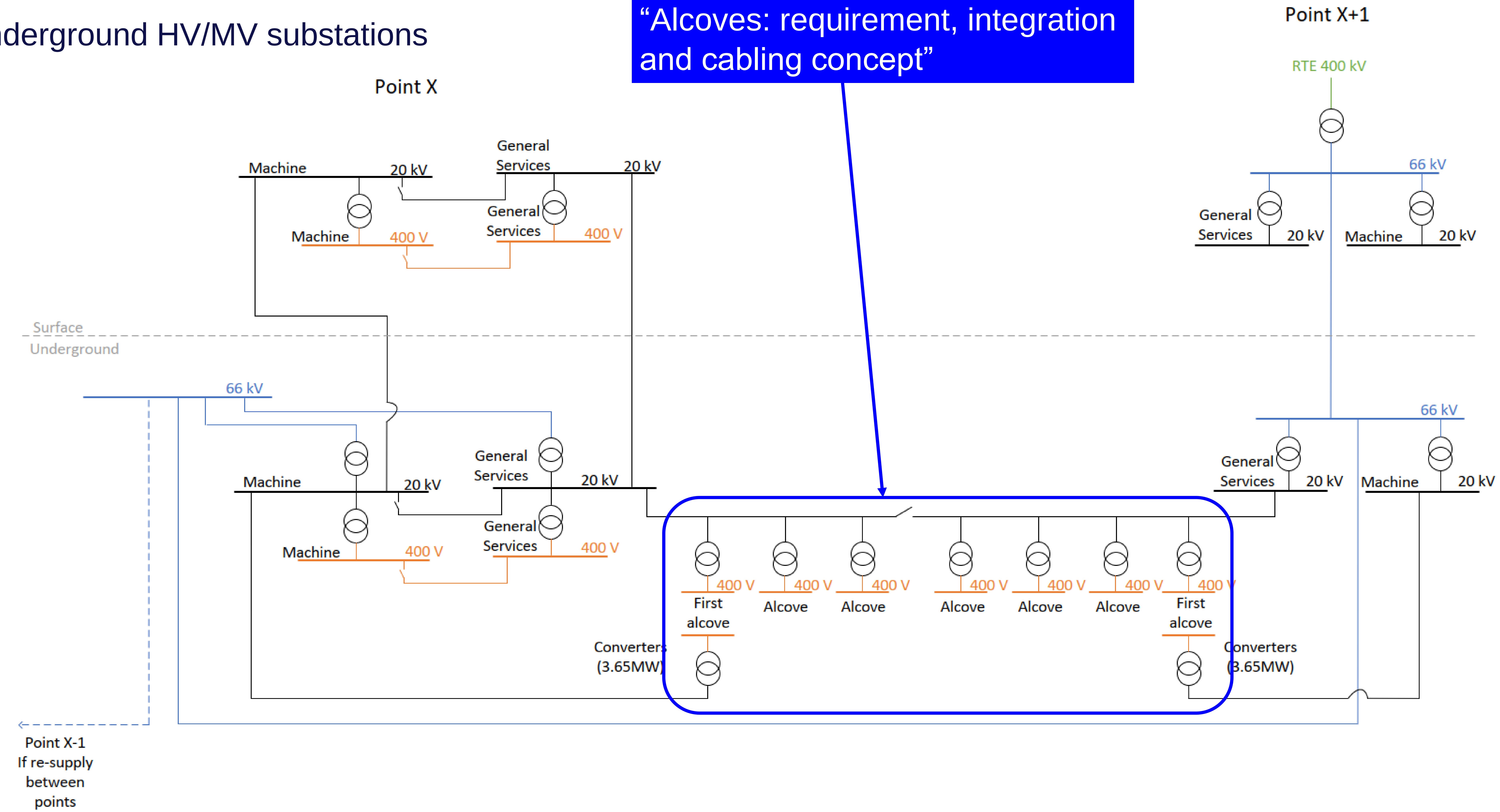
Benefits:

- Power at High Voltage (HV) closer to the main loads
- Avoid a double cabling between surface and underground

Disadvantages:

- Space occupation underground
- Technologies adapted for underground more expensive (and today considered feasible up to 72.5 kV)
- Cooling of the underground galleries

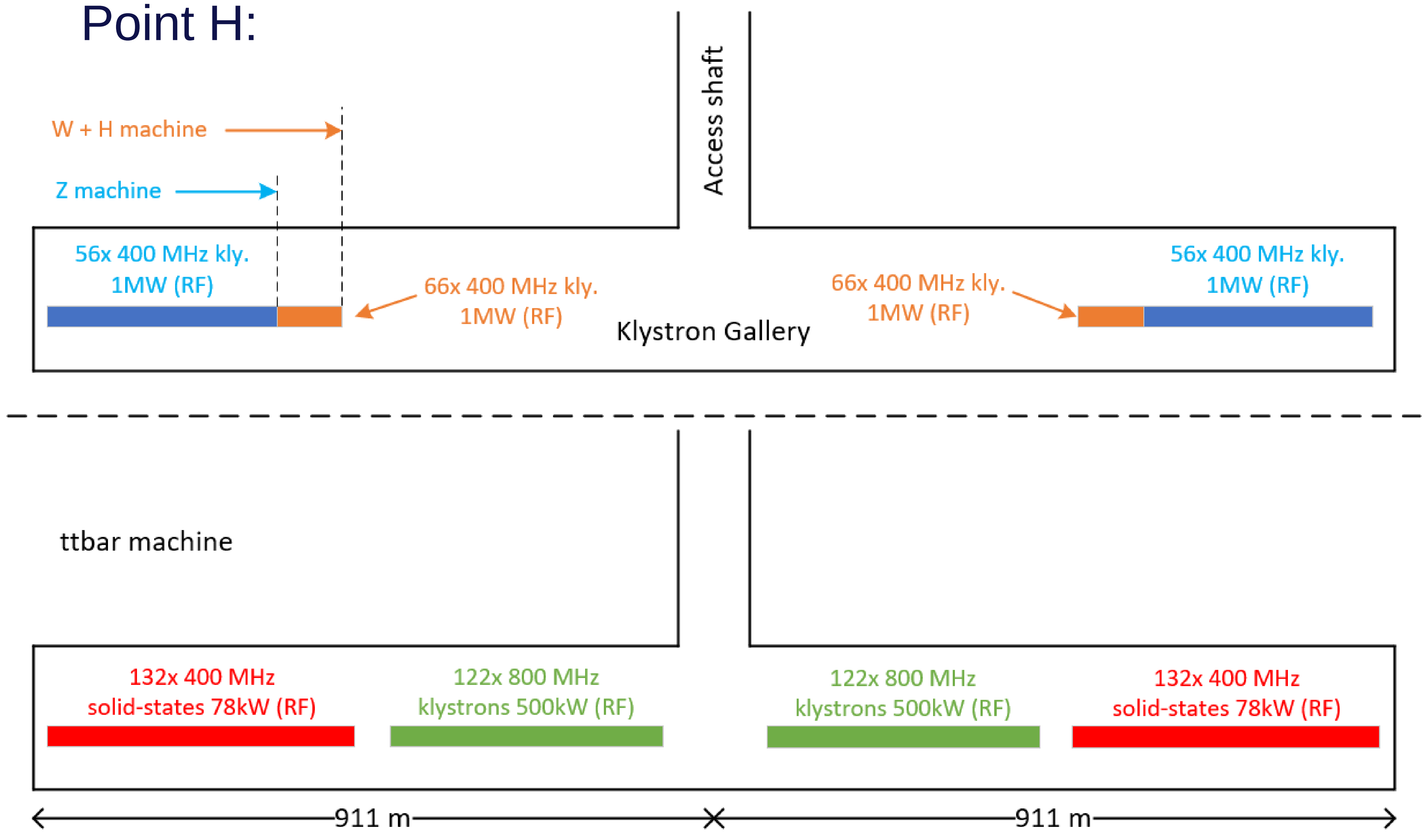
For more details on the electrical distribution of the alcoves:
Tuesday 6th June at 3:52pm
“Alcoves: requirement, integration and cabling concept”



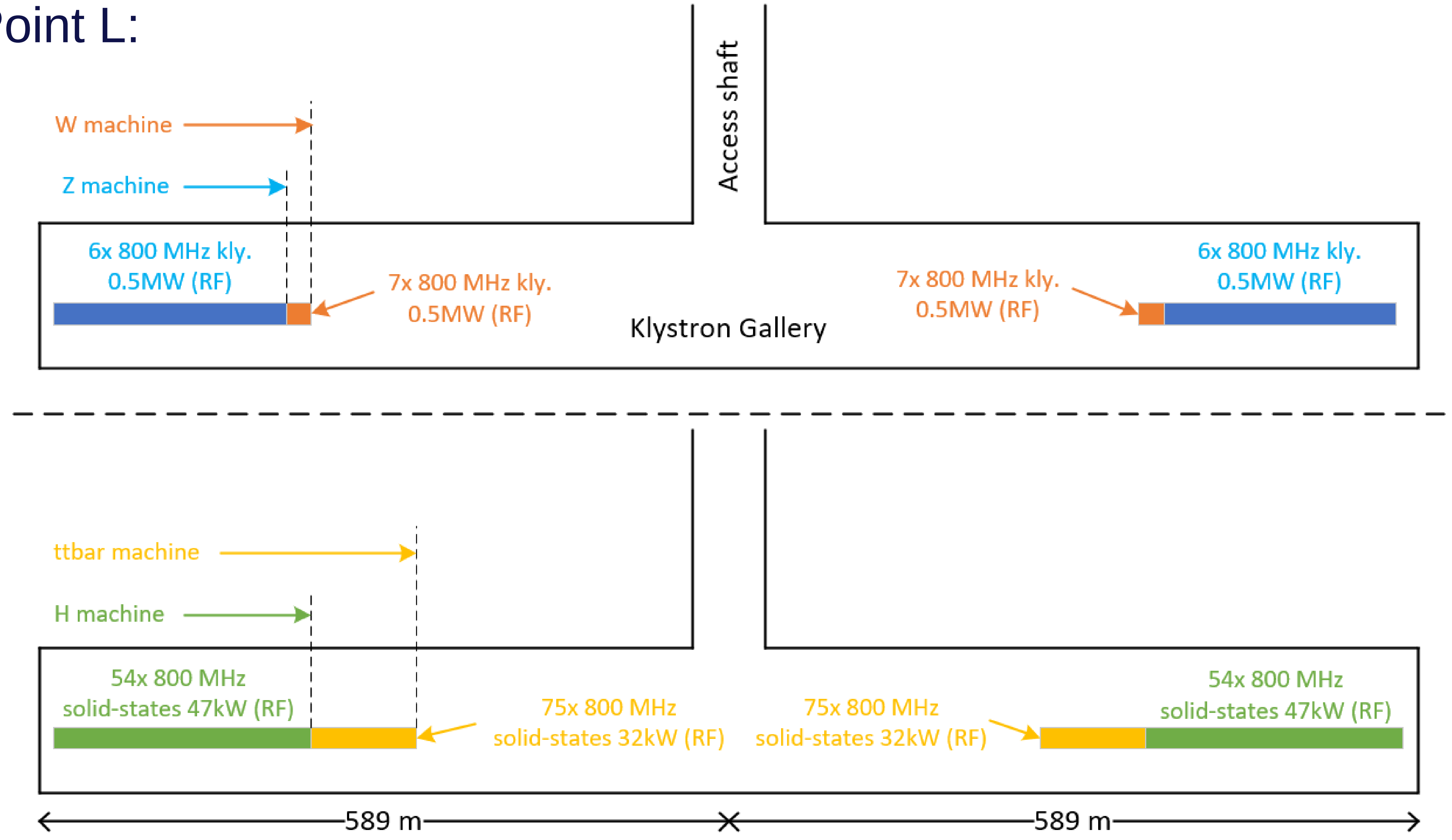
Downstream electrical distribution for RF points

Machine	Z		W		H		ttbar		
	Collid.	Boost.	Collid.	Boost.	Collid.	Boost.	Collid.	Collid.	Boost.
RF frequency - type	400-kly	800-kly	400-kly	800-kly	400-kly	800-SS	400-SS	800-kly	800-SS
# of klystrons	112	12	132	14	132	x	x	244	x
# of S.S. modules	x	x	x	x	x	108	264	x	150
Tot. Installed [MW]	**149**	**8**	**175**	**9,4**	**175**	**10,5**	**42,8**	**164**	**13,8**
Tot. El consumption [MW]	**134**	**6,8**	**133**	**6,7**	**133**	**8,2**	**33,4**	**106**	**7,8**

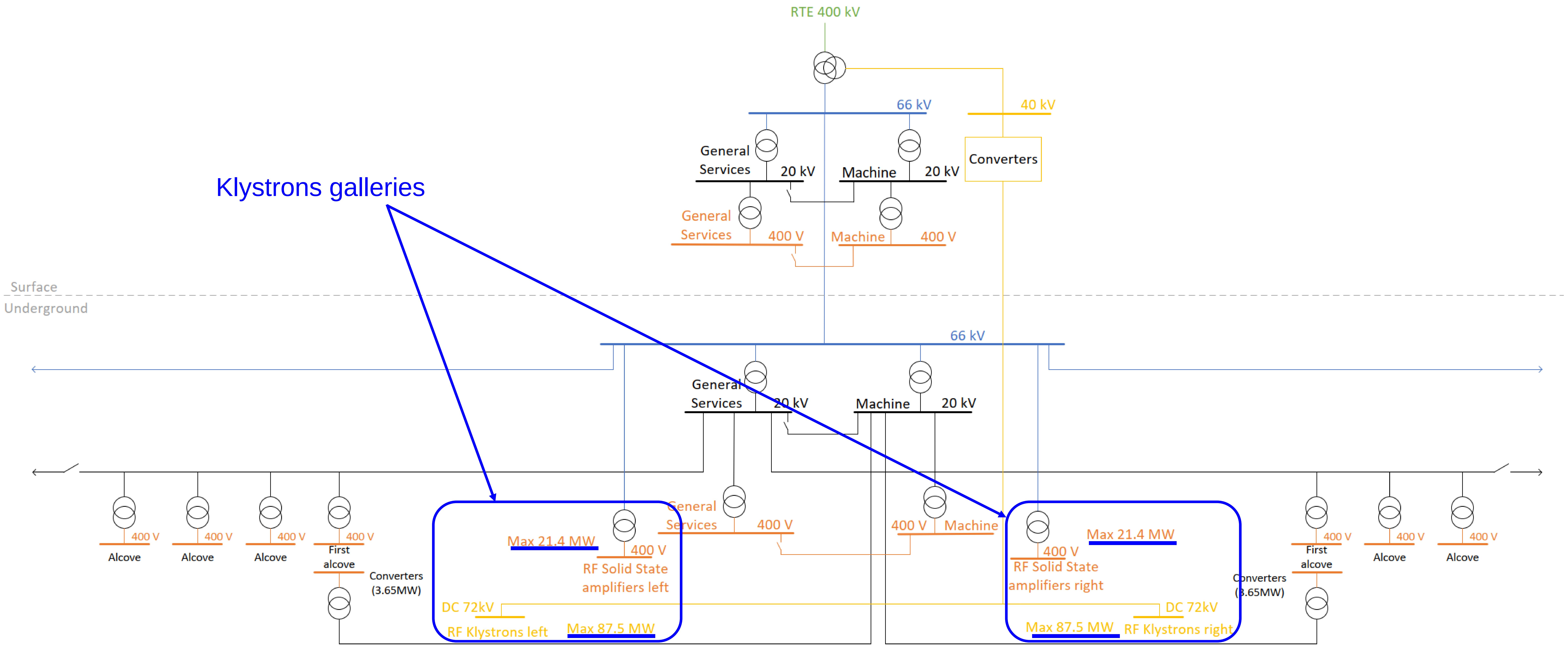
Point H:



Point L:

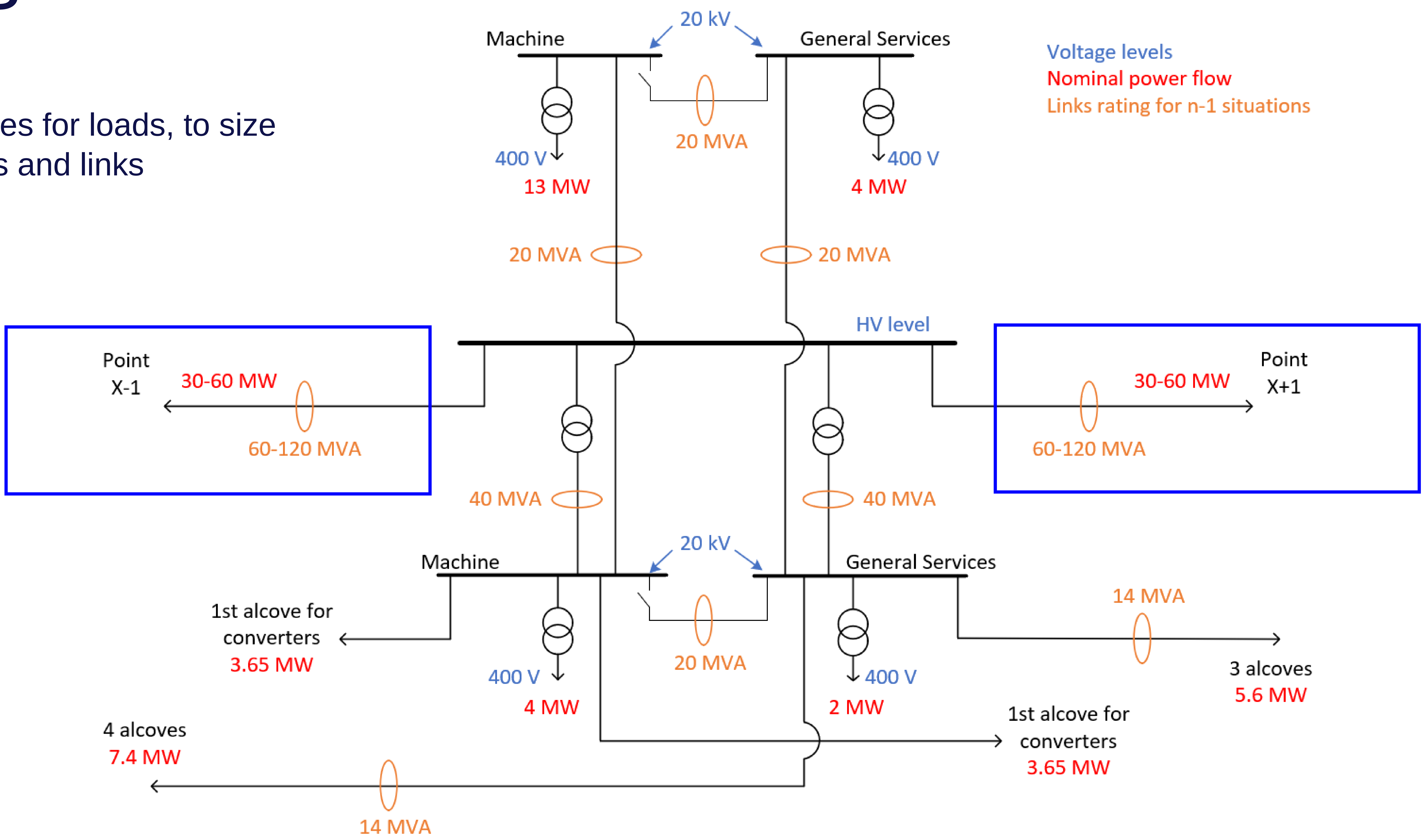


Downstream electrical distribution for RF points



Downstream electrical distribution for other points

Maximum values for loads, to size the substations and links



Conclusion and next steps

Today

- The progress on the users' requirement definition allowed **to develop the baseline of 2022 FCC week**
- The concept of underground transmission network and substations has been studied and is the object of a **cost/benefit analysis**
- The selection of the voltage transmission level is **under finalization**
- The power flow of the main links is being assessed taking into account a n-1 scenario
- Power supply of RF points **well developed**
- Concept and preliminary sizing of underground distribution **well developed**

In the future

- Iterations to update 3D electrical integration of tunnels, galleries and alcoves **still to be performed**: an impact on the current baseline of integration is expected, **item to be addressed by the end of 2023**
- Summary of updated requirements for cooling and ventilation **still to be performed: to be addressed by the end of 2023**
- **Feasibility study for the installation of a High Voltage cable in the tunnel will be launched in 2023**
- Study of secured network **will start by the end of 2023**

- Users' power requirements still under definition, and studies still ongoing**: the presented results shall be considered preliminary**

Conclusion and next steps

Opportunities:

- **Staging** (if compliant with FCC reliability and availability requirements):
  - HV substations and transmission loop
  - Downstream electrical equipment (e.g. RF supplies)
- **FCC-hh**:
  - High-level infrastructure ready
  - Possible re-use of electrical systems installed in RF points of FCC-ee
- Integration of internal renewable power generation
- Use of **DC alternative solutions** to at least part of the powering infrastructure, e.g. supply of power converters
  - *Comparison of AC-DC solutions in the pipeline of the WG*
  - *Still the connection to RTE AC grid shall be ensured*

For more details on the DC alternatives:
Thursday 8th June 9:24am by Manuel Colmenero Moratalla
“DC Networks for the Powering of the FCC”

Thank you for your attention