FUTURE CIRCULAR COLLIDER

UPDATE ON FCC ELECTRICAL NETWORK AND GRID CONNECTION

Mario PARODI (CERN EN-EL) – TIWG – Electricity & Energy Management WP

FCC week 2022, Paris

Many thanks to J.P. Burnet, D. Aguglia, F. Blanquez, M. Colmenero Moratalla, G. Cappai, K. Zielinski for the important support

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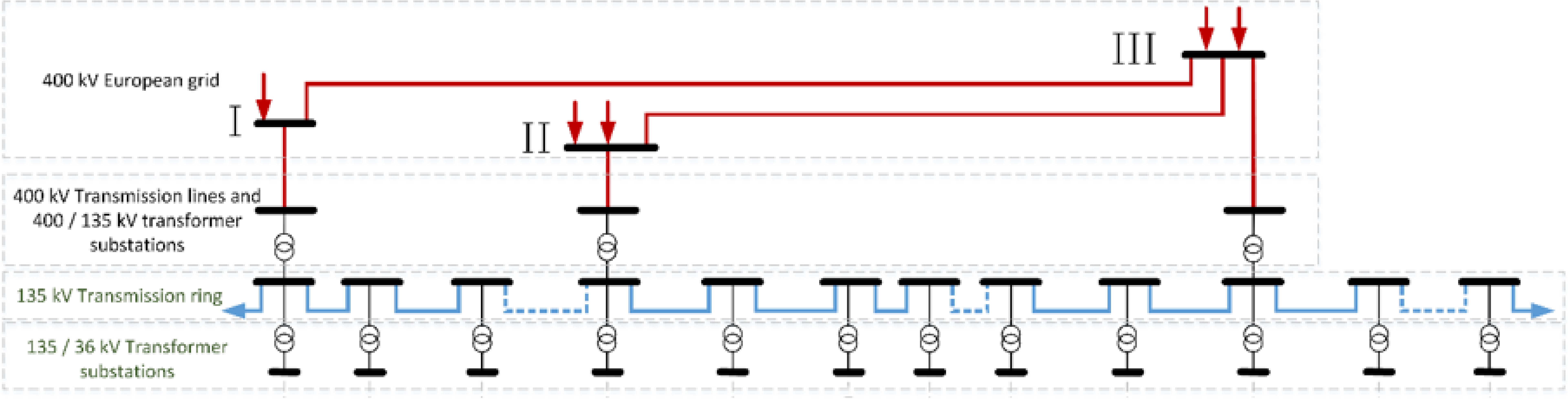
Baseline CDR 2018

Baseline CDR FCC

- 12 Access points
- Maximum target power consumption: 364 MW FCC-ee ttbar (554 MW FCC-hh)
- Based on the layout studied for FCC-hh
- 3 connection points to 400 kV RTE grid (A, E, J)
- n. 3 220 MVA 400/135 kV per connection point
- Internal 135 kV transmission open loop



Load Estimate FCC-ee

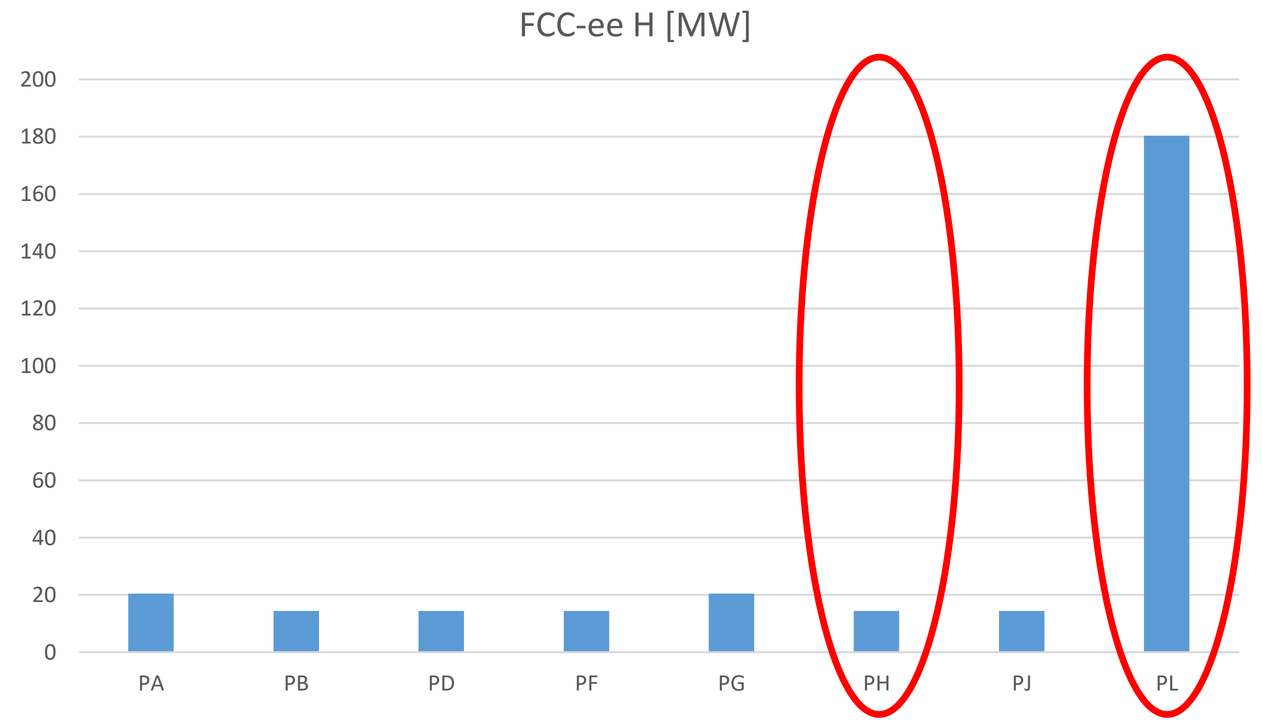
Updated estimate

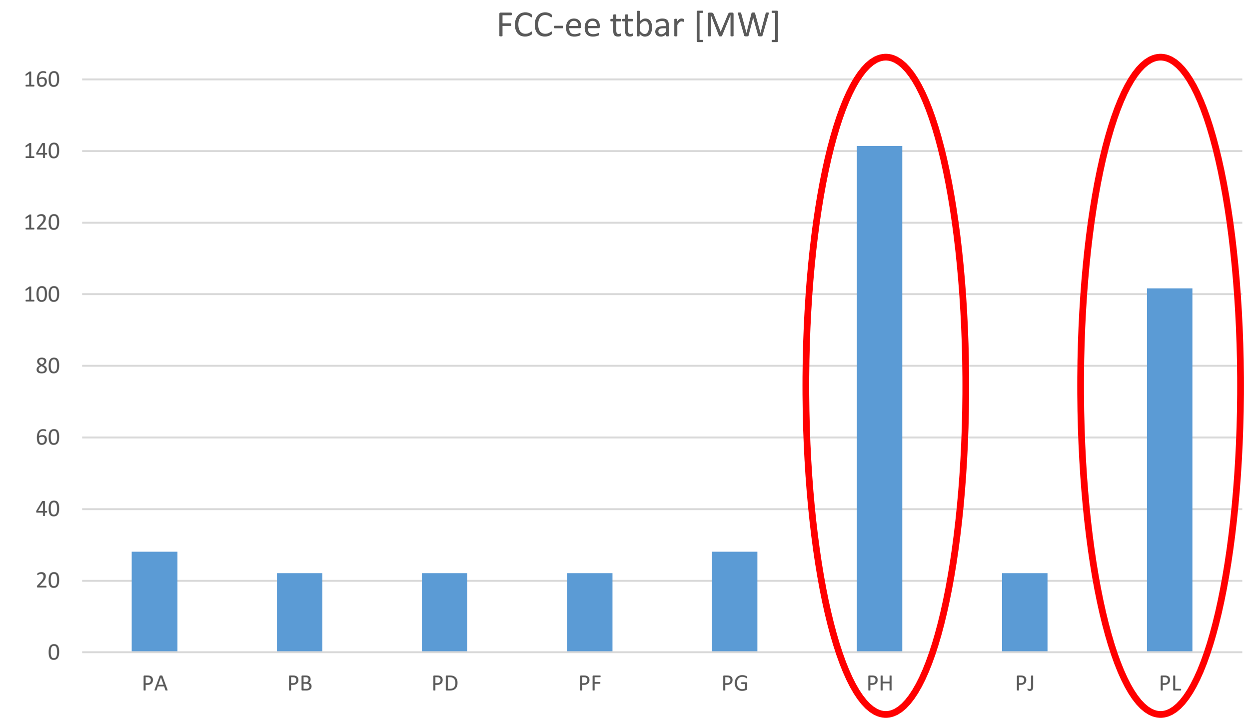
- Maximum target power consumption FCC-ee: **387 MW (ttbar)**
- **Highly unbalanced request**:
  - Point H and Point L: 100 ÷ 180 MW
  - Other points: < 30 MW
- Focus on evolution of RF point:
  - Point H: 14 MW (up to H) 141 MW (ttbar)
  - Point L: 180 MW (up to H) 102 MW (ttbar)
- **Challenge for an optimized solution that fits all phases**

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

For all details:
Thursday 2nd June at 11:00
"Update of the power demand for FCC-ee"
from Jean-Paul Burnet

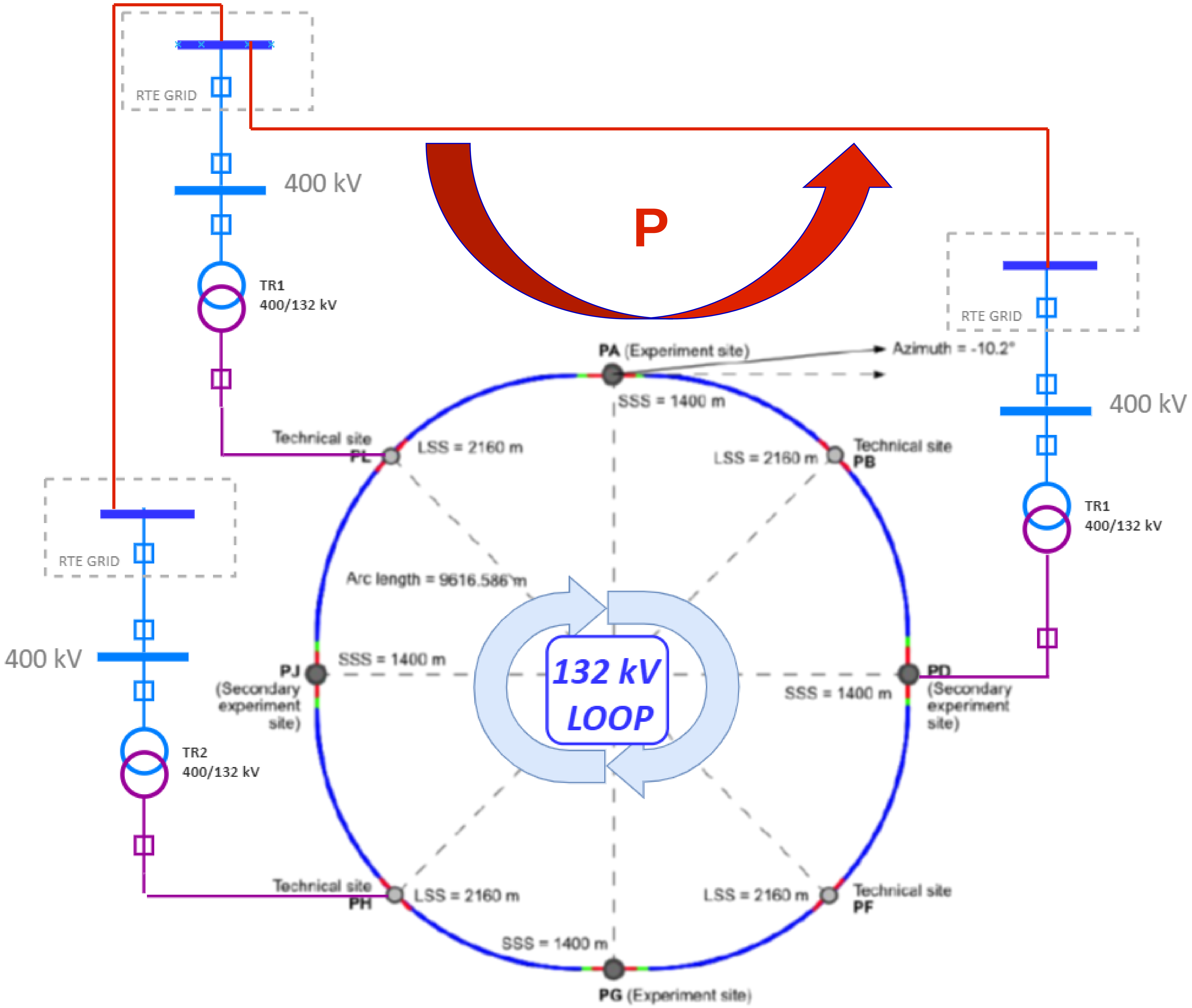




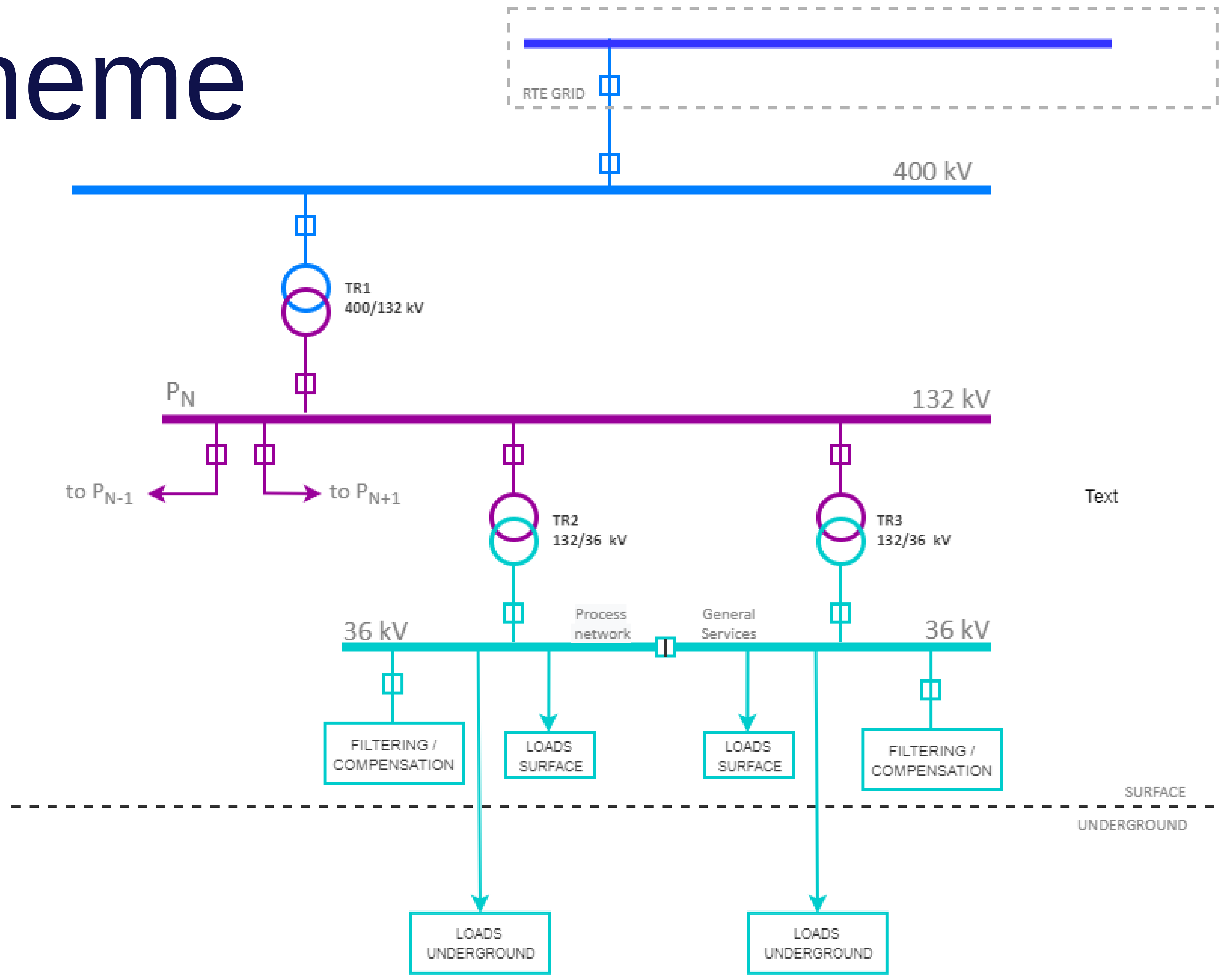
High Voltage Network Scheme

Present baseline

- Adaptation to the **8-points** new layout
- Confirmation of **n. 3 connection points to RTE grid**:
  - n. 2 HV connections at RF points
  - n. 1 HV connection at point D (preferred) or point F (alternative)
- **Internal 132 kV transmission loop**
  - Running through the main tunnel
  - Cost of investment Vs. FCC RAMS requirement: analysis to be performed
  - High cable capacitance:
  - → Charging current
  - Proposal: move to **closed loop**:
  - → High reliability
  - → Existing control and protection technologies suitable for the topology
  - → Balanced power flow
  - → **<u>Need a confirmation from RTE about feasibility</u>**

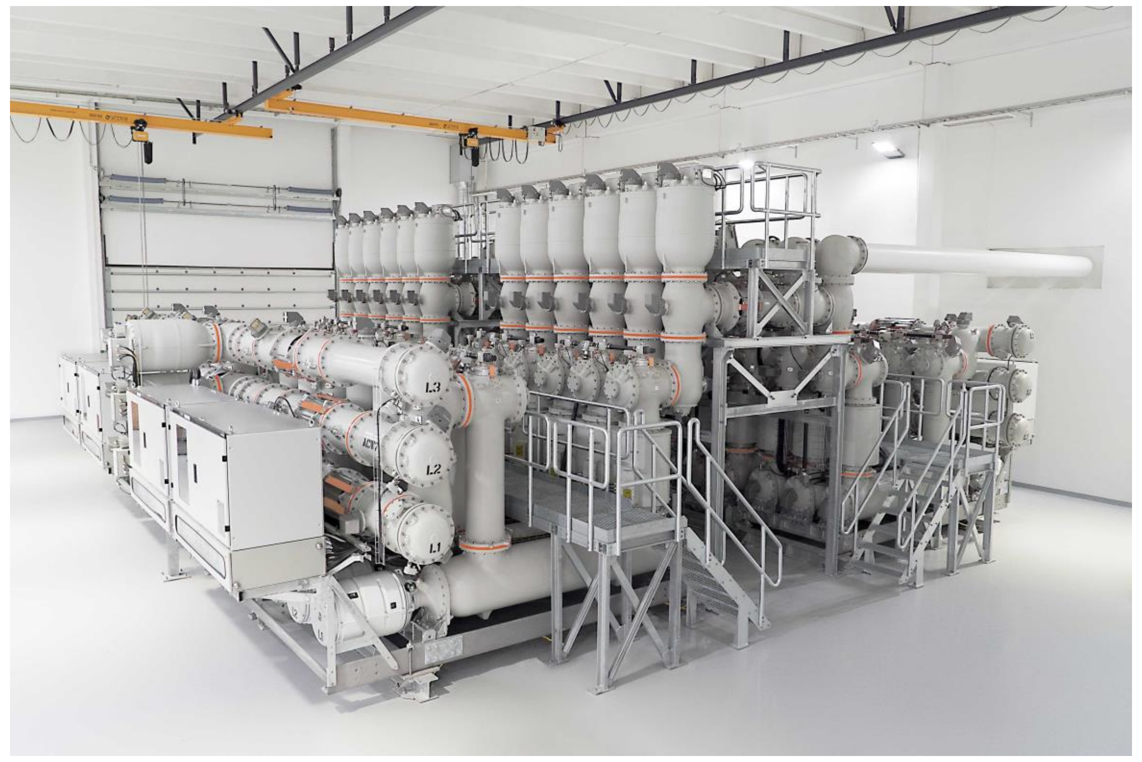


High Voltage Network Scheme



High voltage transmission and distribution

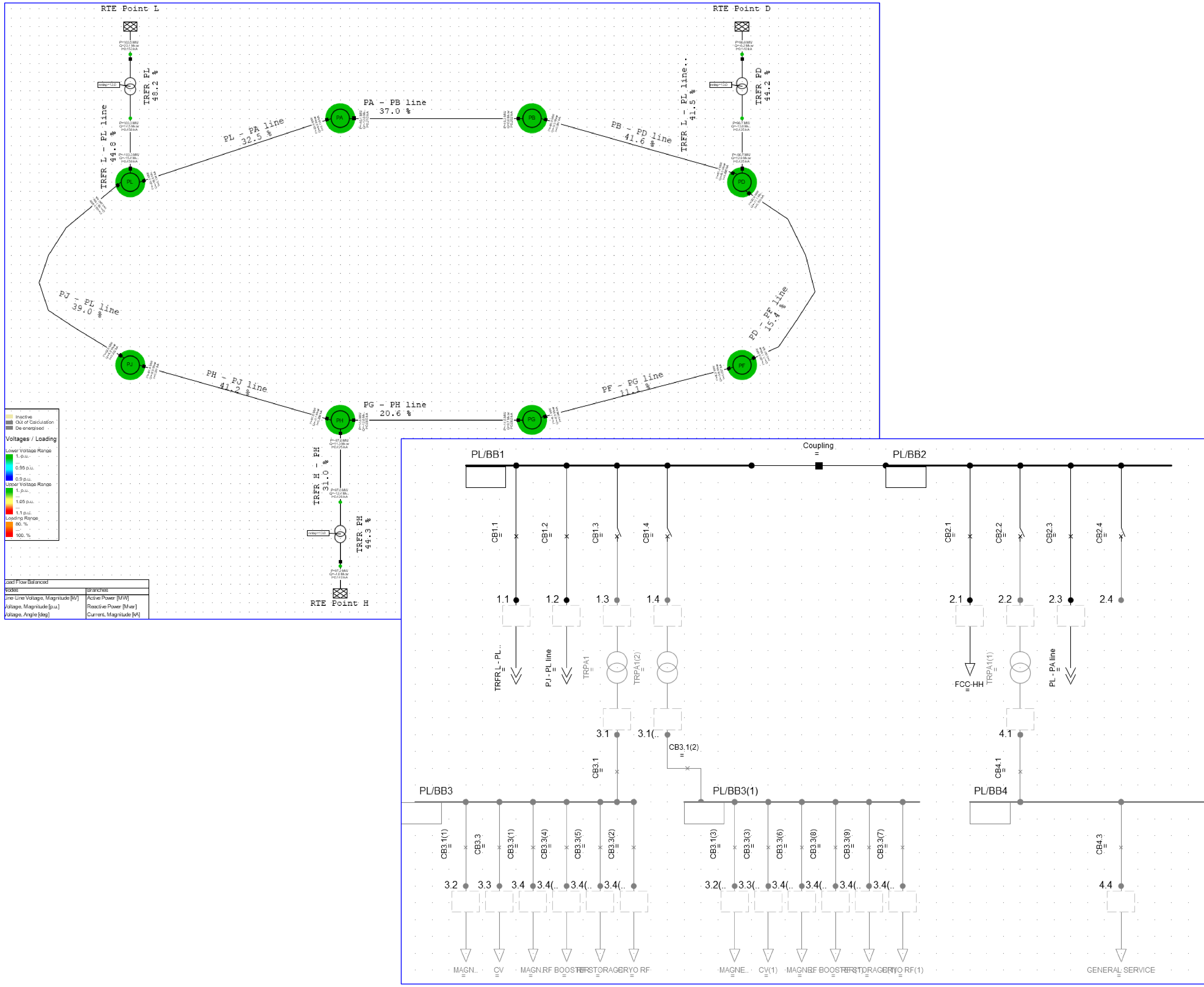
- **n. 3 400/132 kV AIS substations** (points H, L, D)
- For all points: **n. 1 132/36 kV AIS substation**
- **36 kV distribution network** for :
  - Process (machine) and General Service
  - **Surface buildings**: distribution links to each building
  - **Underground facilities**: distribution links to service galleries and alcoves
  - Each link: MV/LV transformer + Power Center
- Total surface of HV substations:
  - Points H, L, D: approx. **12,000 m²**
  - Other points: approx. **4,000 m²**
  - **Opportunity:** GIS substation (approx. factor 4 of surface reduction, higher cost, today's technology based on greenhouse insulating gases at high voltage)



Network Software Model

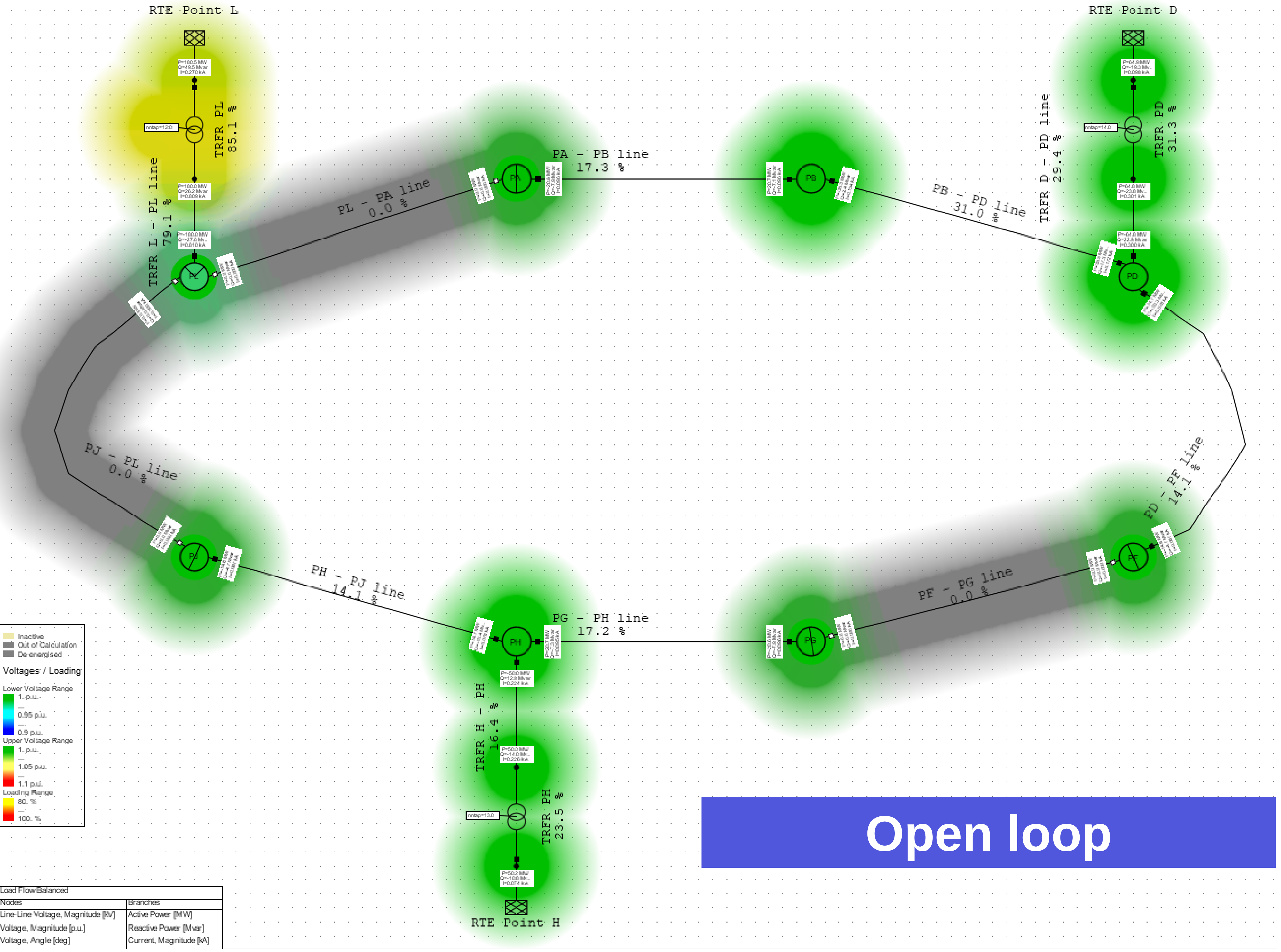
FCC network model available since 2022

- **Aim:** support network analysis and sizing with reliable data, and ease decision making process
- **Main features**:
    - Expandable from main topology to detailed schemes
    - Multi-scenarios simulation (loads/network schemes)
    - Voltage analysis and regulation modelling
    - Contingency analysis
    - Power flows and losses reporting
    - Fault analysis
    - Transient analysis
    - Cost modelling
- Steady state (load flow) performed on **400/132 kV levels**
- **Focus on two stages of FCC-ee:**
    - H: maximum power in one point (PL)
    - ttbar: maximum total power

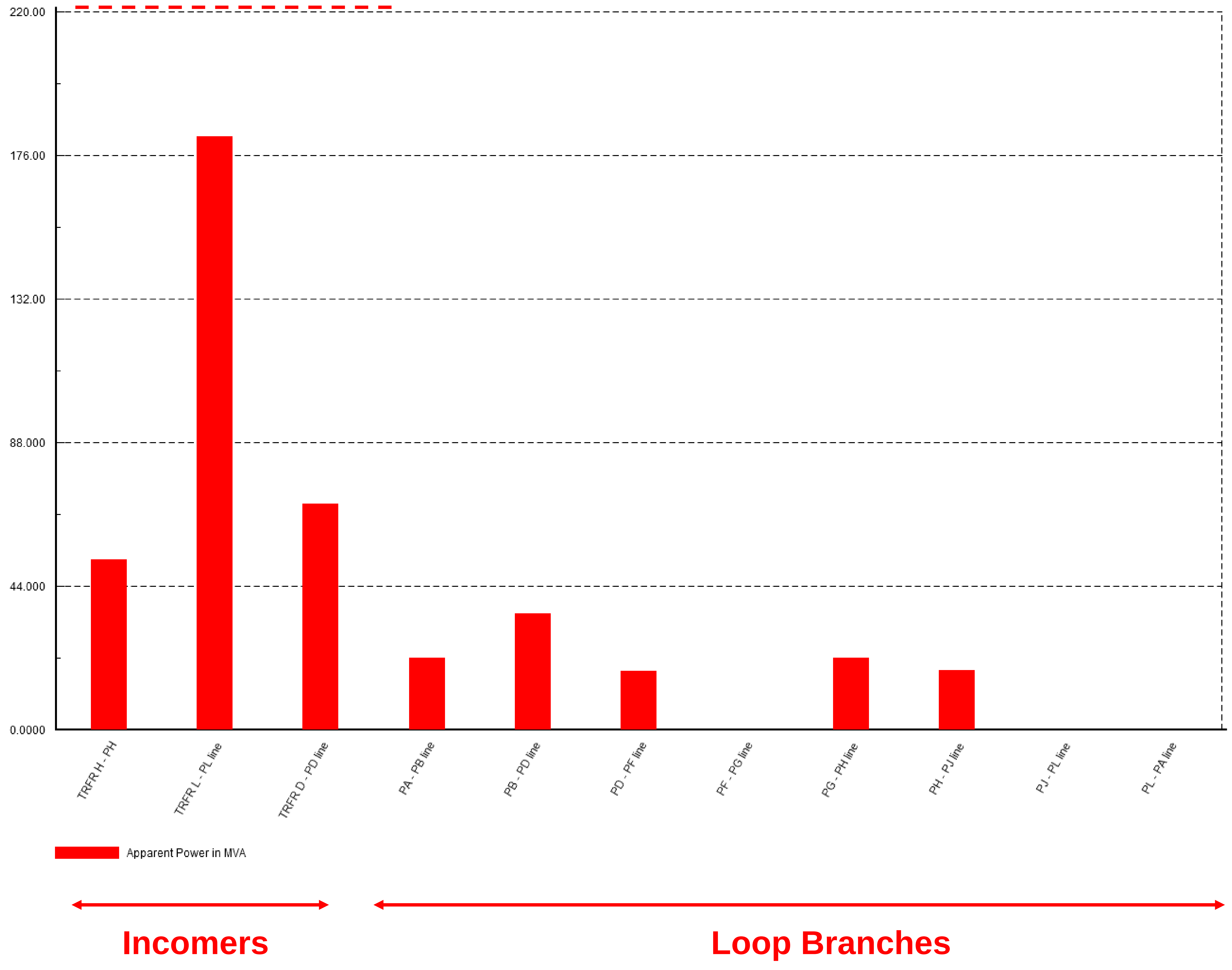


Load Flow Simulations

FCC-ee H – Nominal Supply

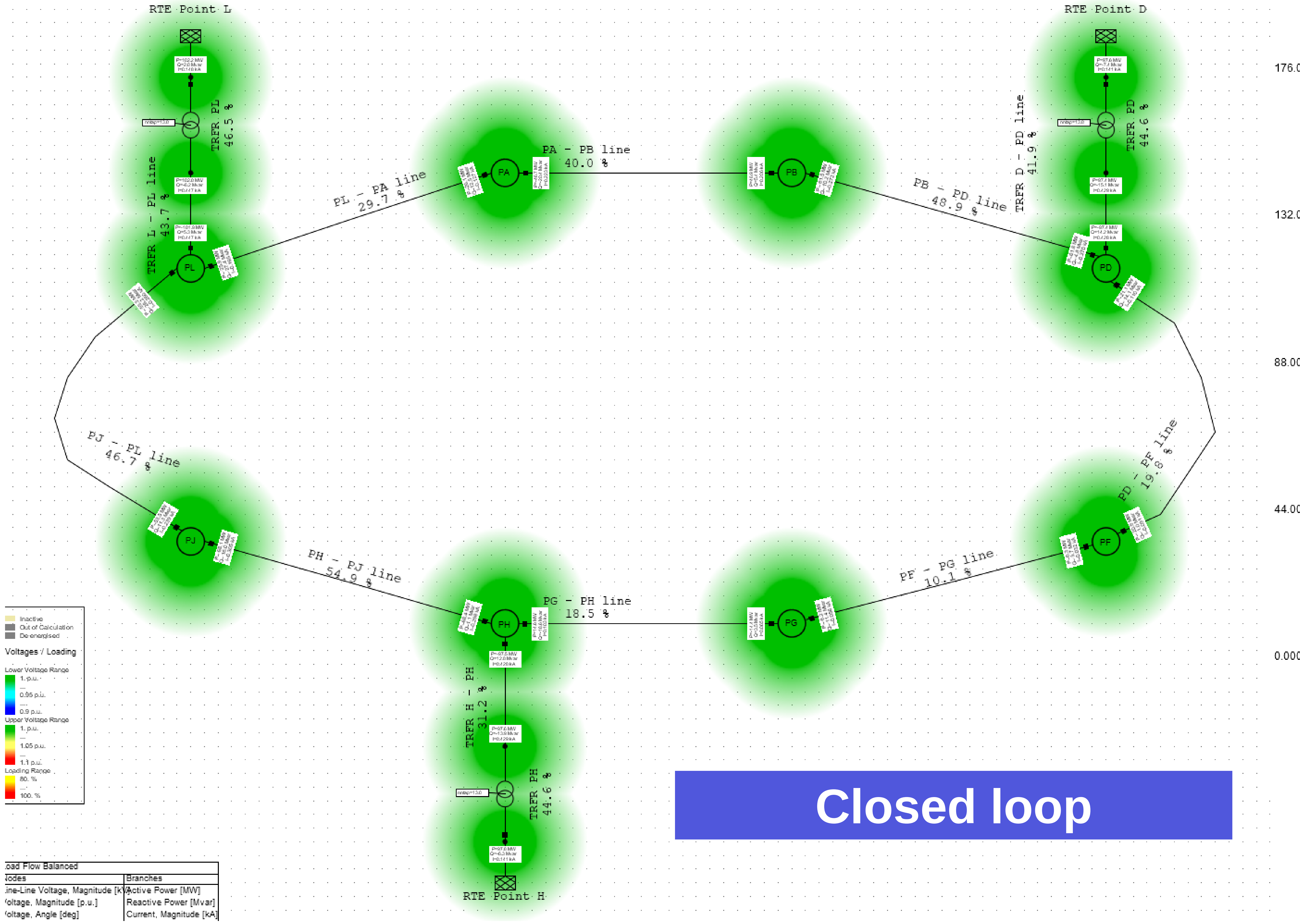


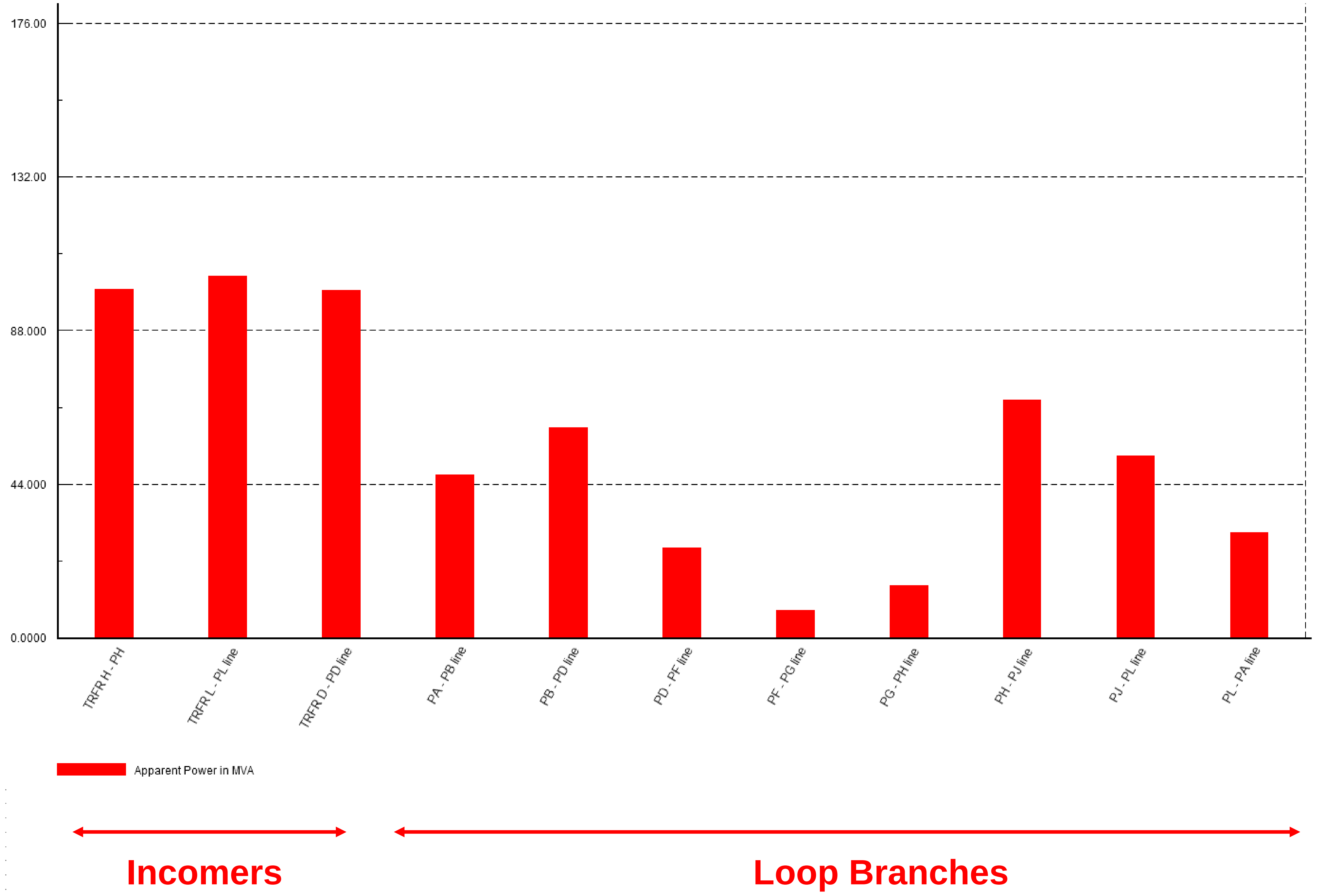
Open loop



Load Flow Simulations

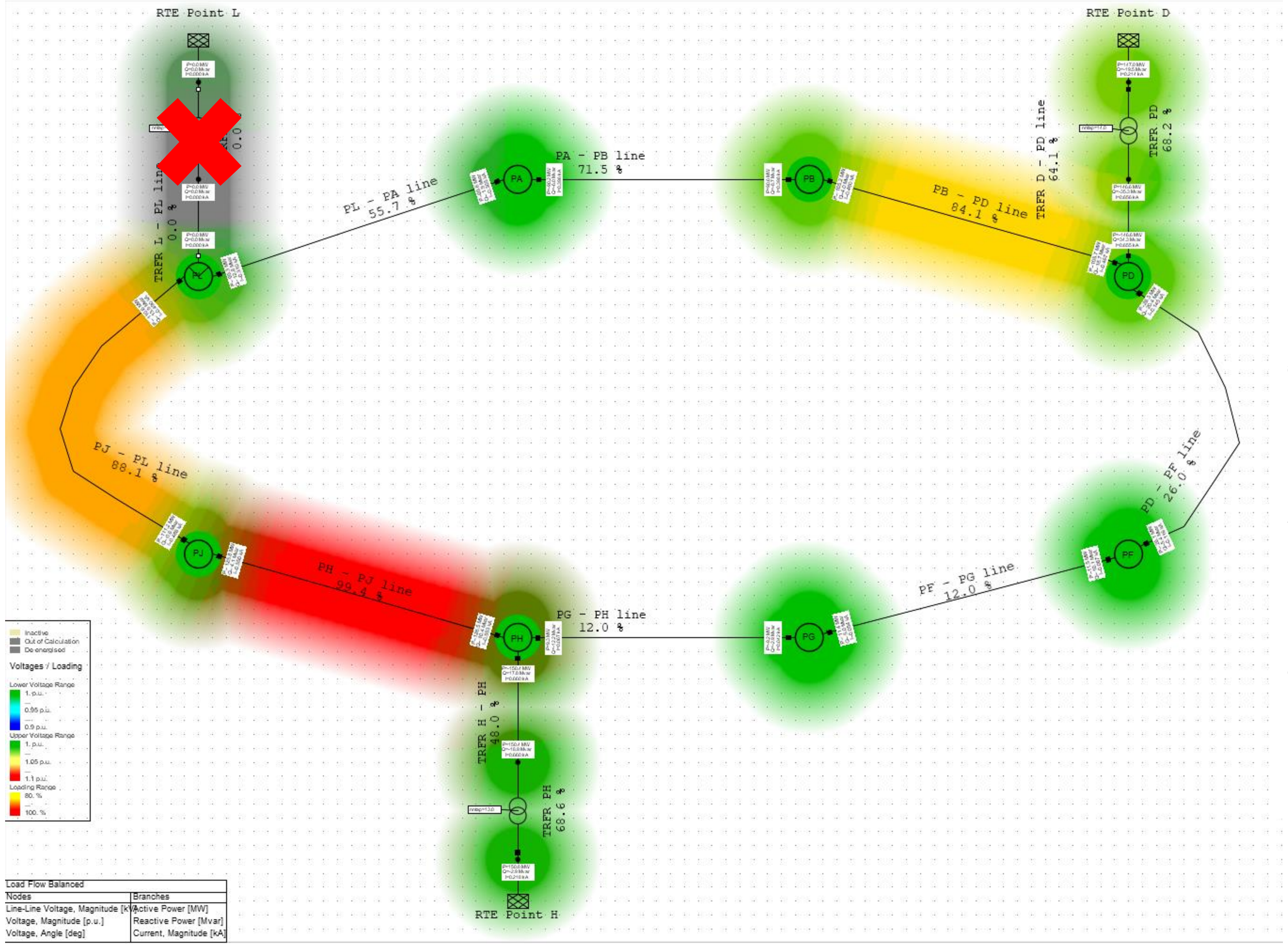
FCC-ee H – Nominal Supply

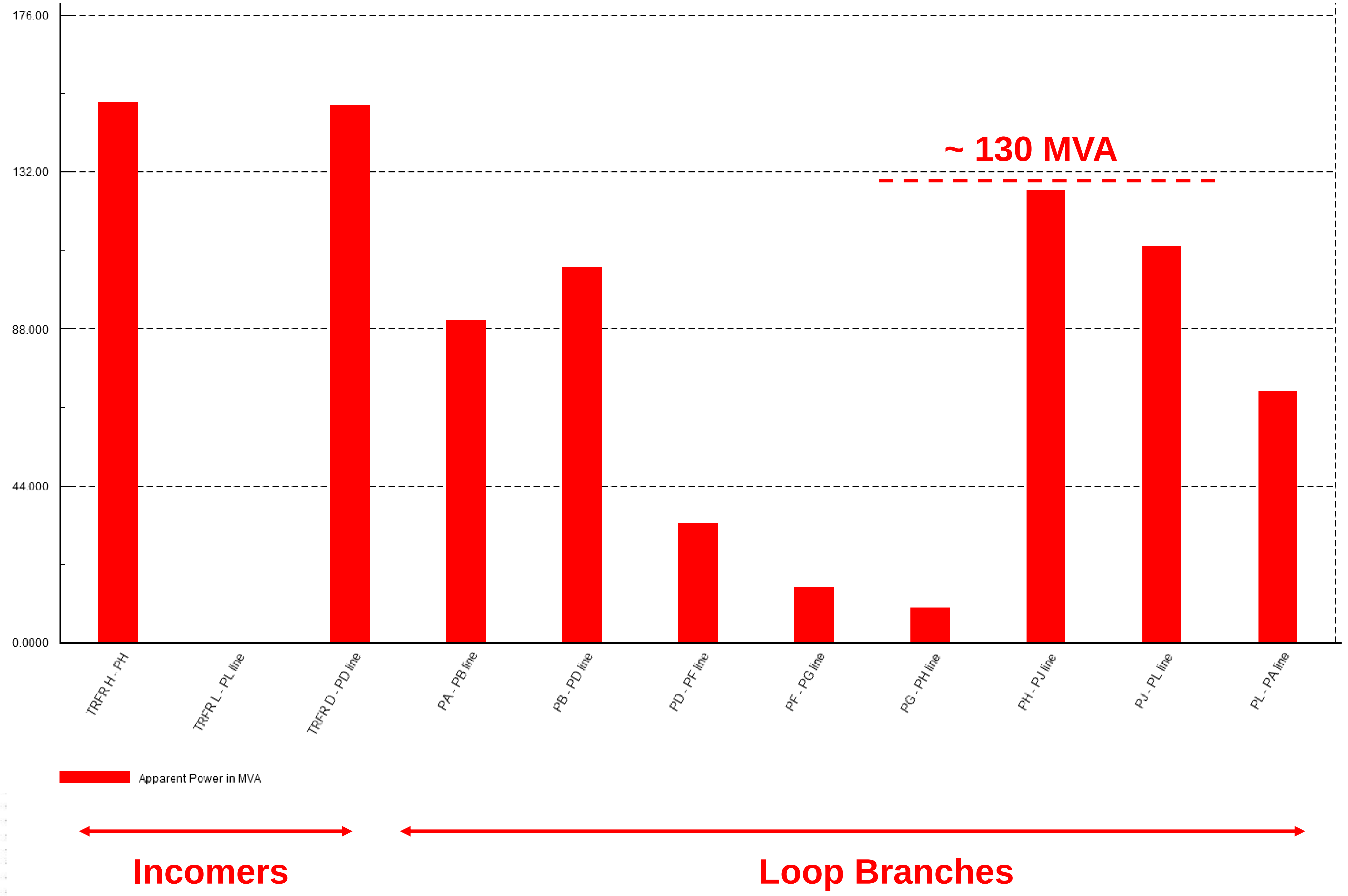




Load Flow Simulations

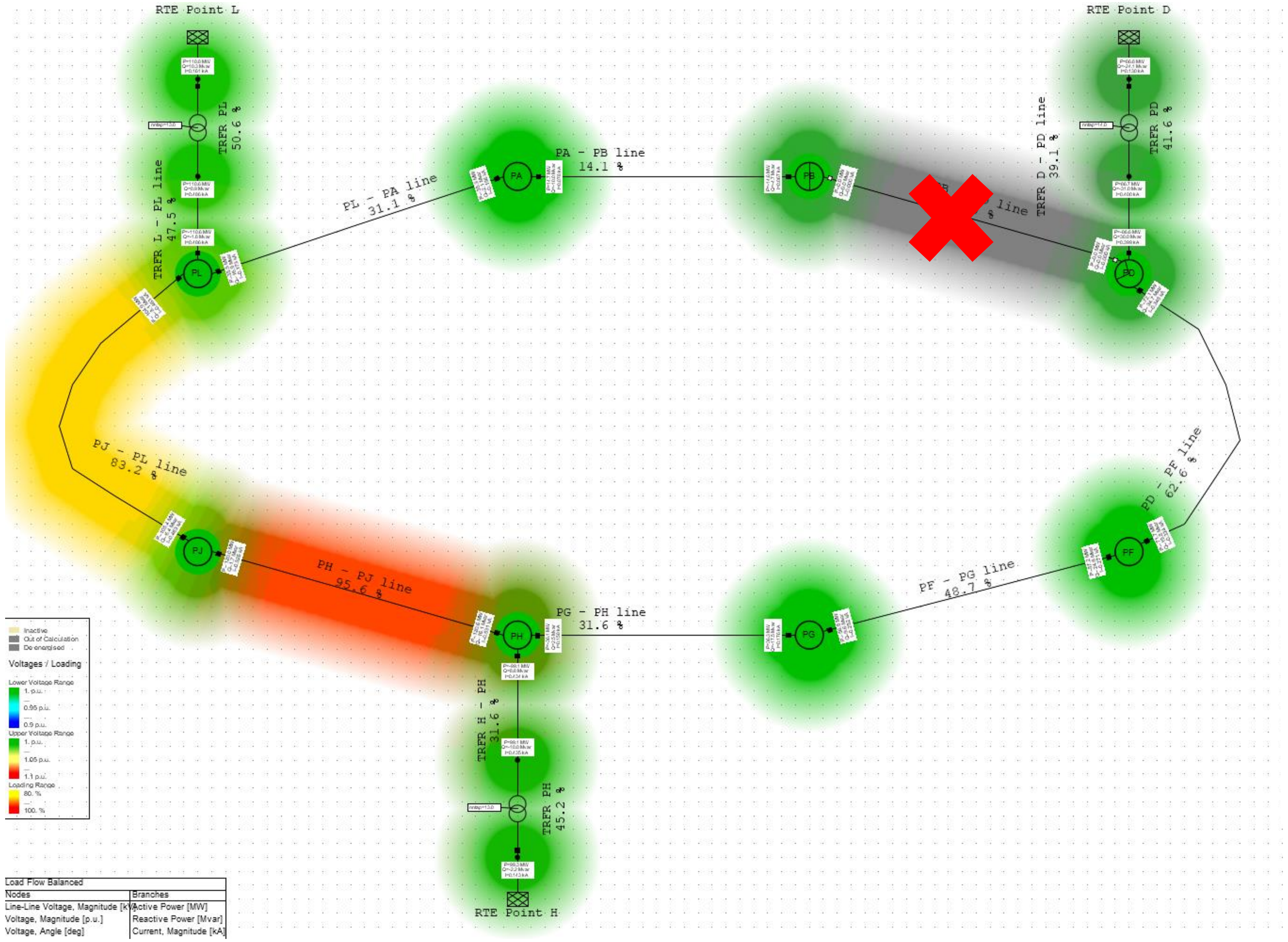
FCC-ee H – Loss of one supply

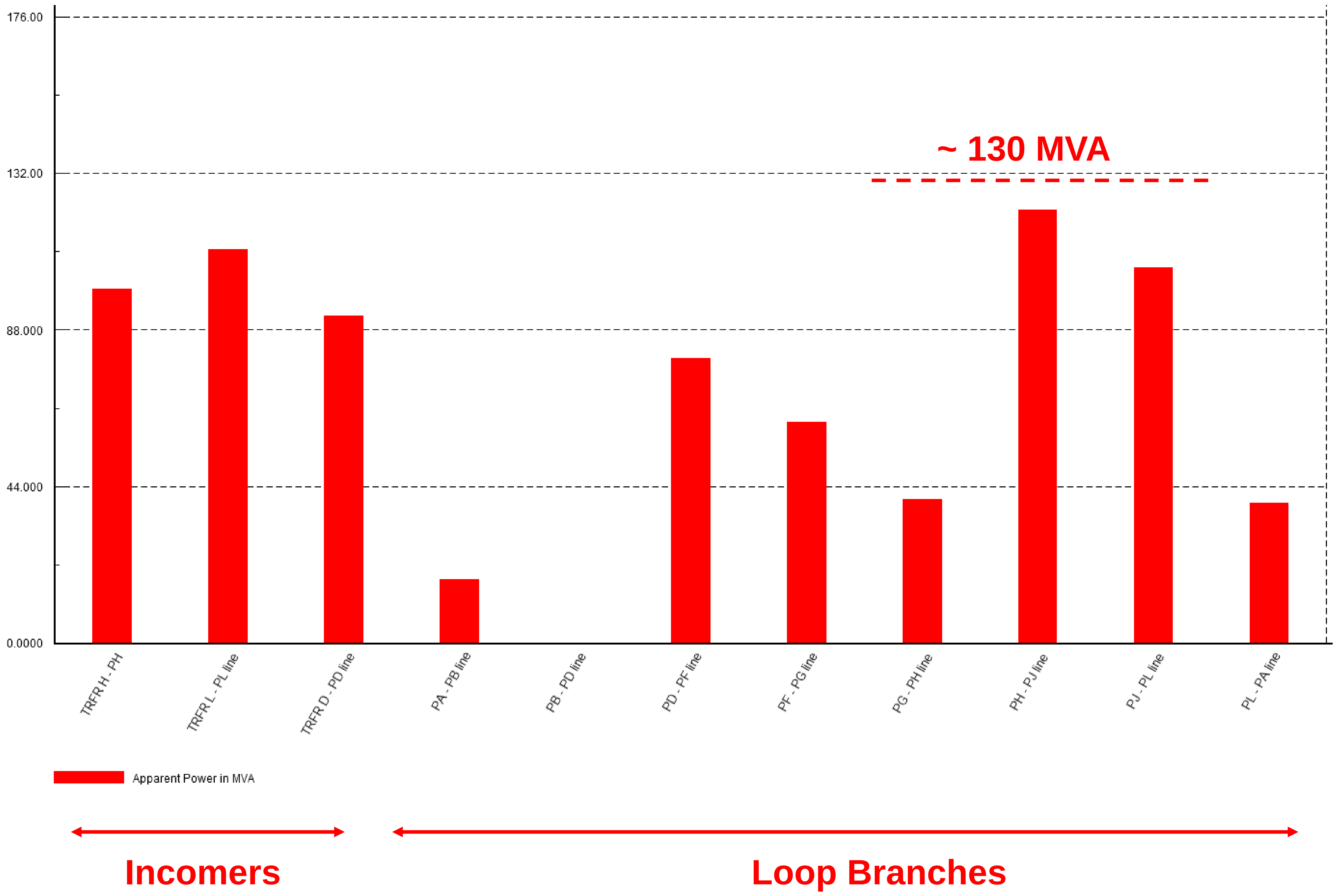




Load Flow Simulations

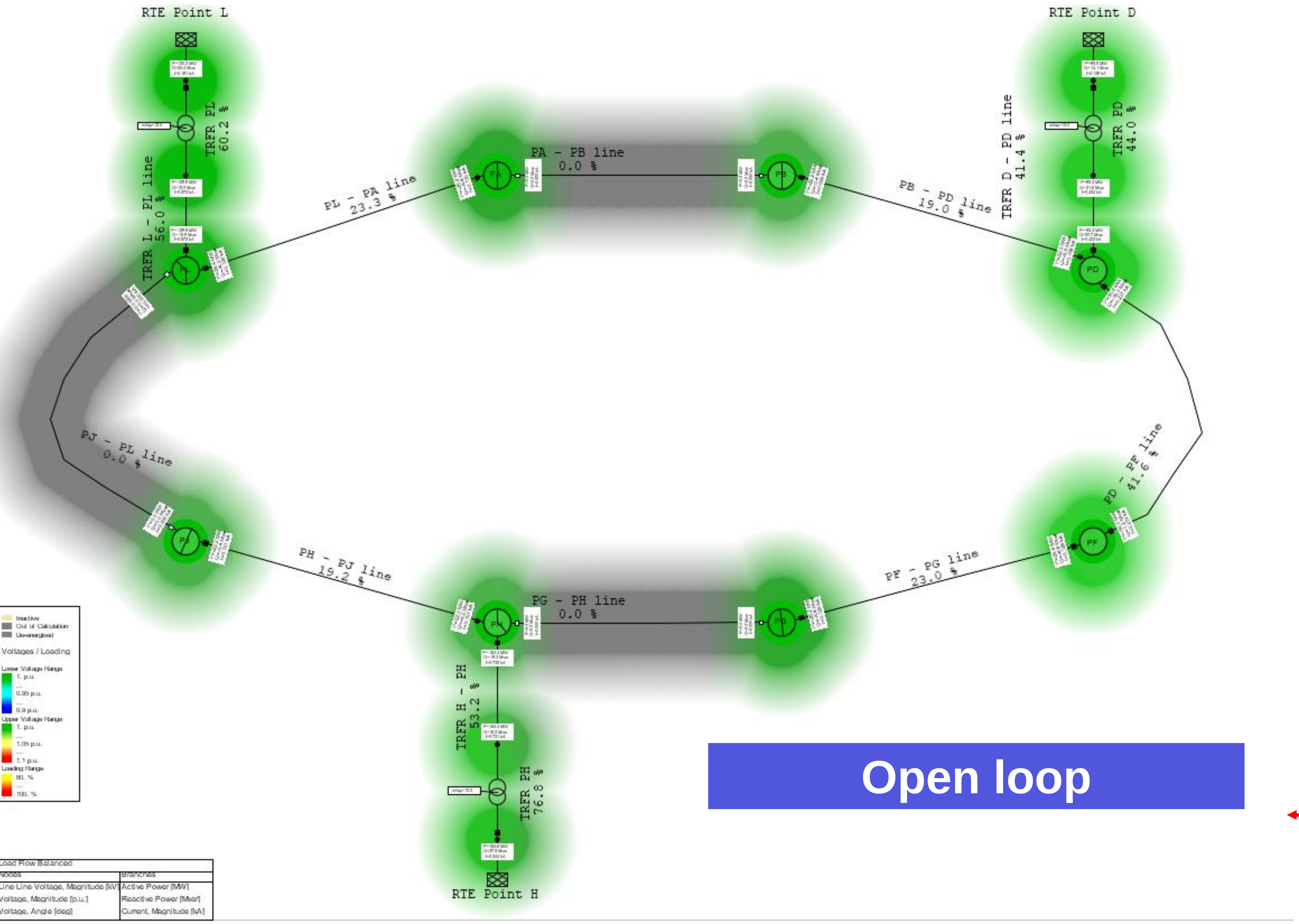
FCC-ee H – Loss of one branch

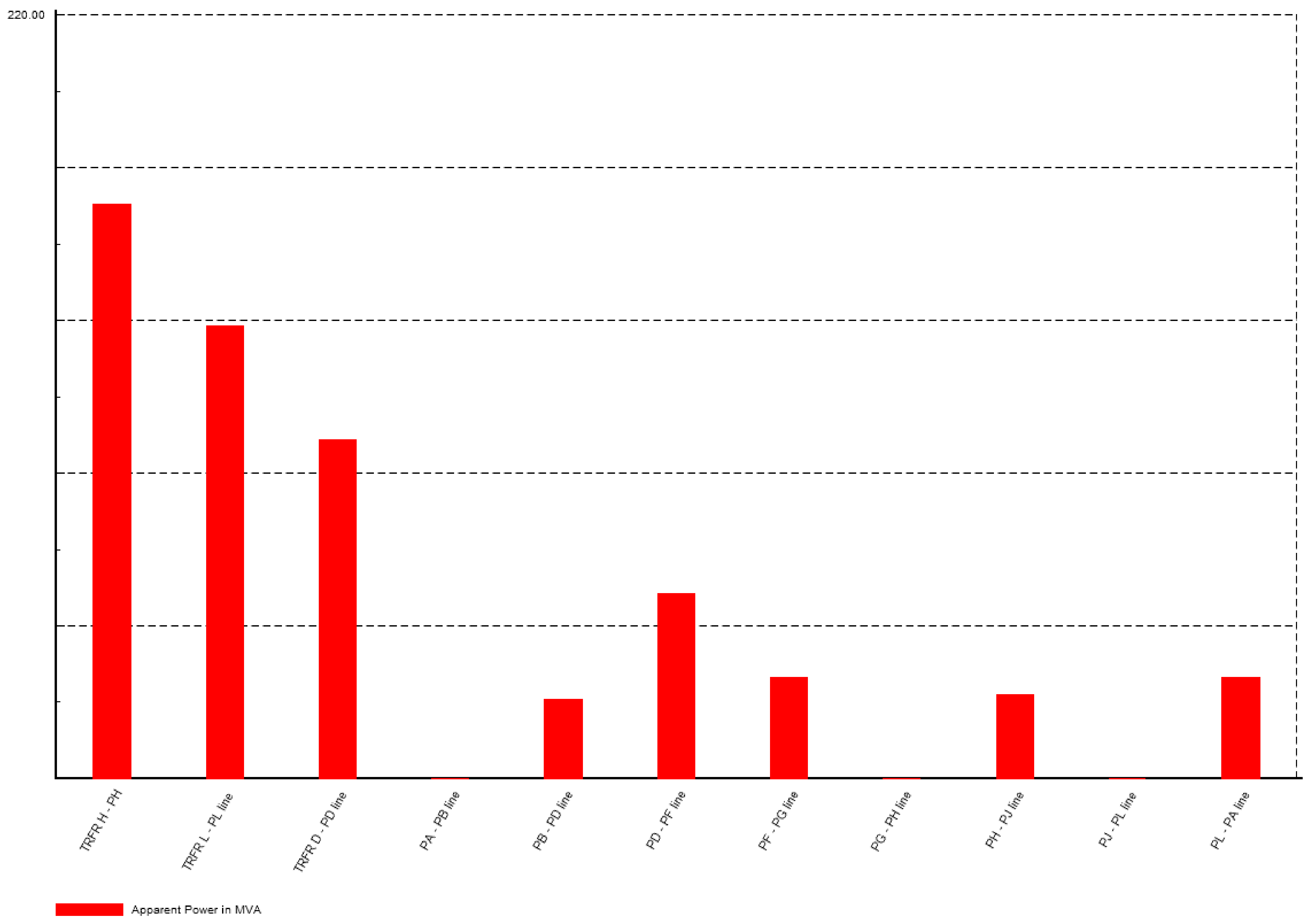




Load Flow Simulations

FCC-ee ttbar





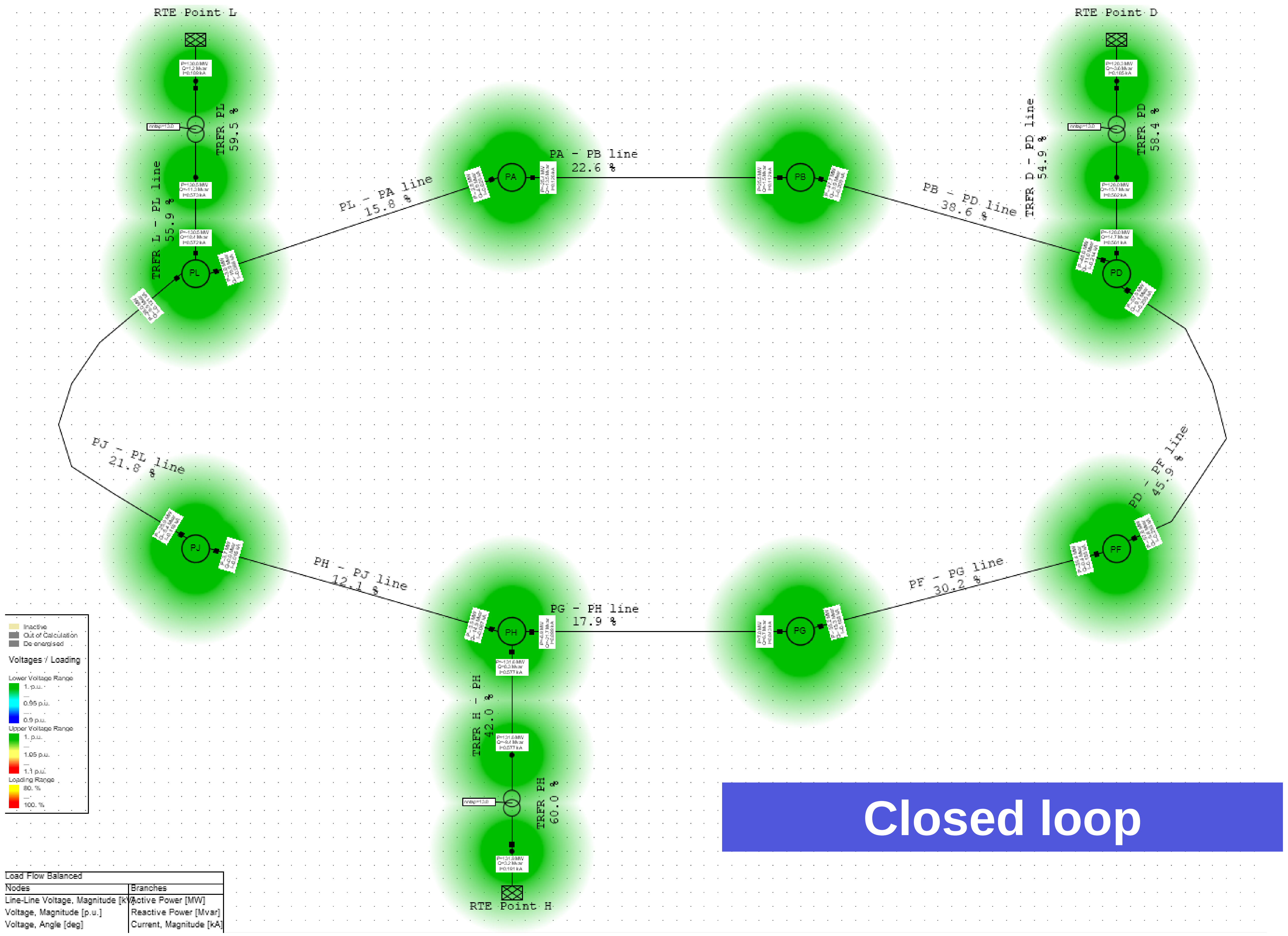
Open loop

Incomers

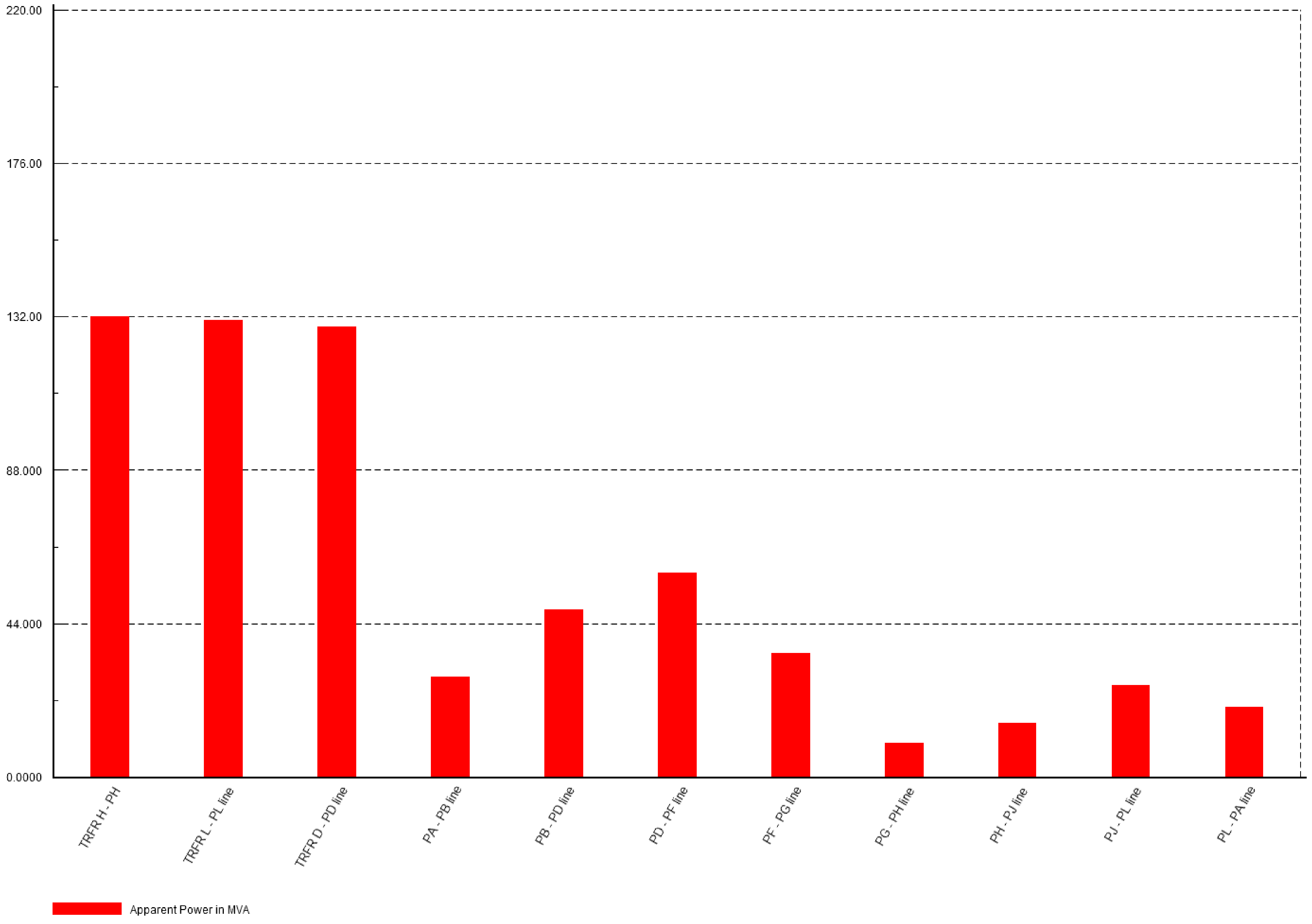
Loop Branches

Load Flow Simulations

FCC-ee ttbar



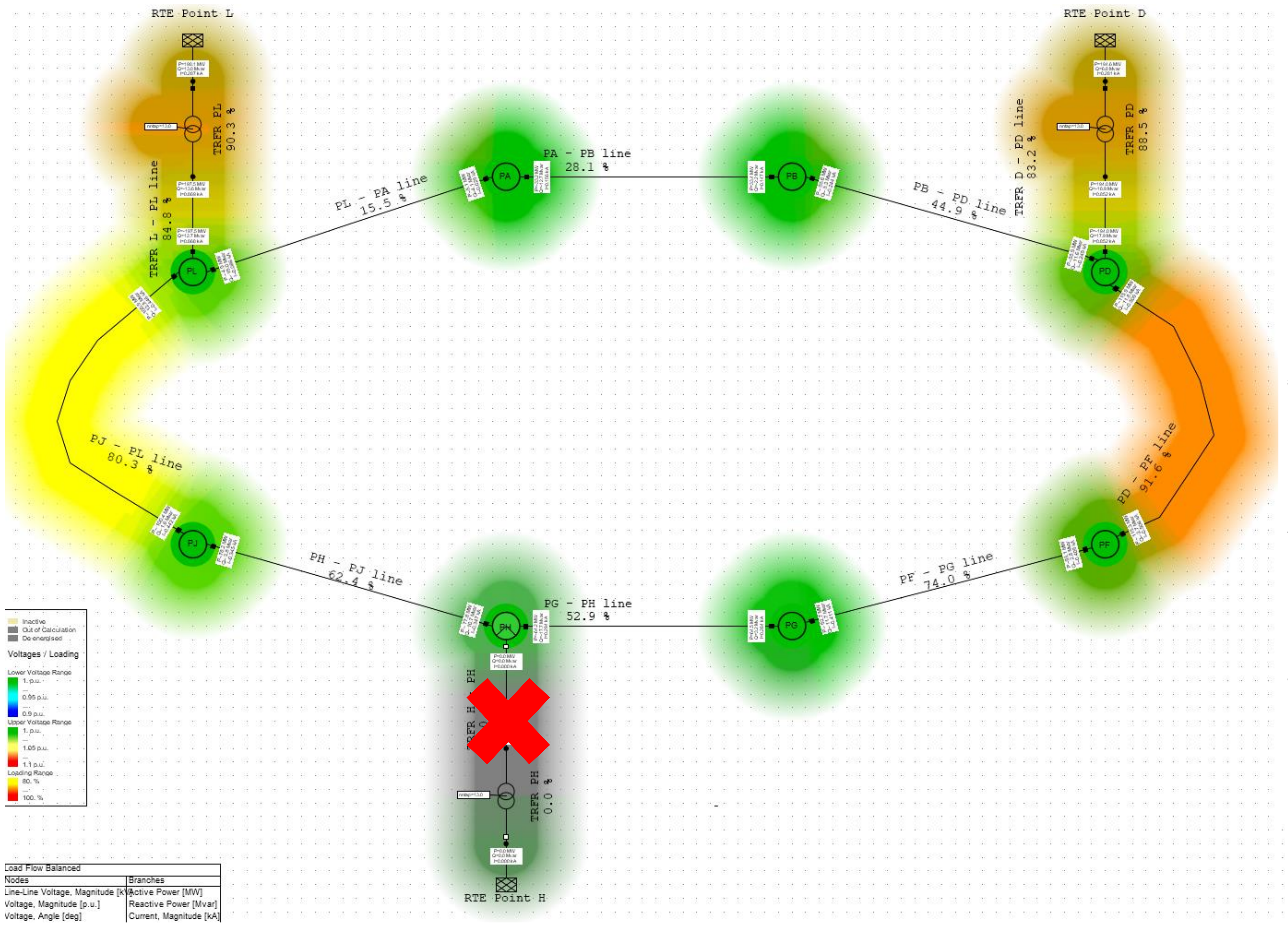
Closed loop

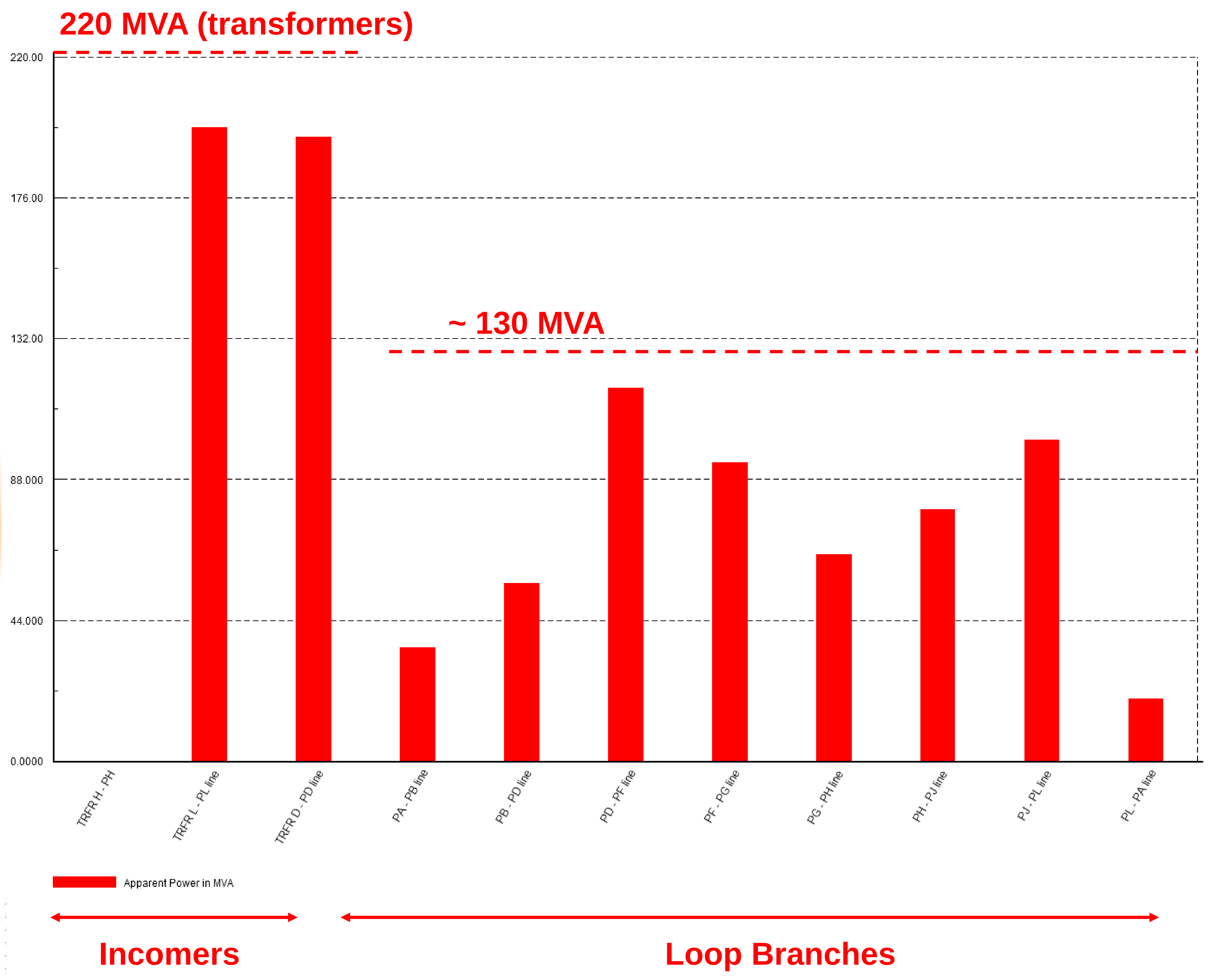


Incomers **Loop Branches**

Load Flow Simulations

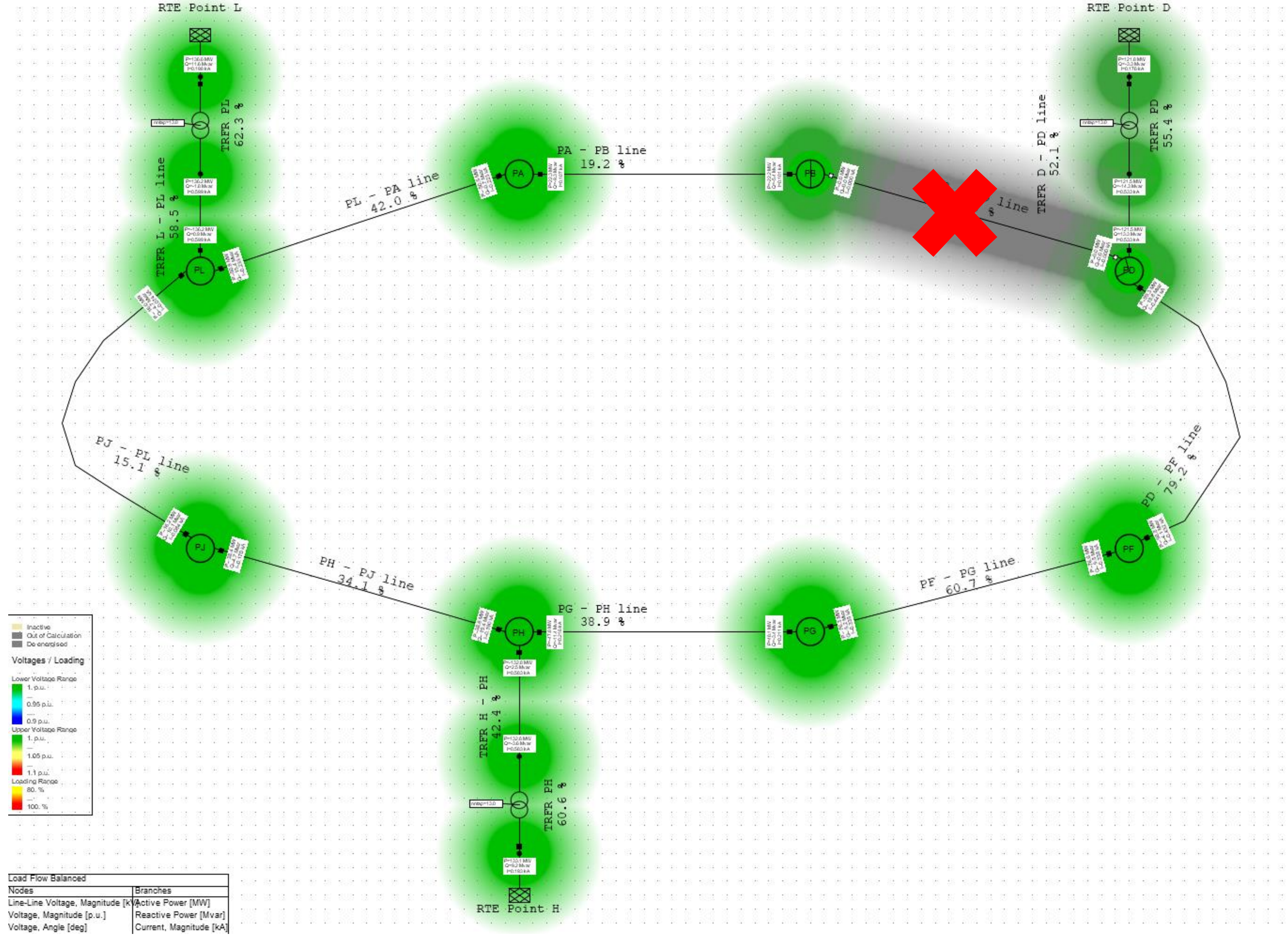
FCC-ee ttbar

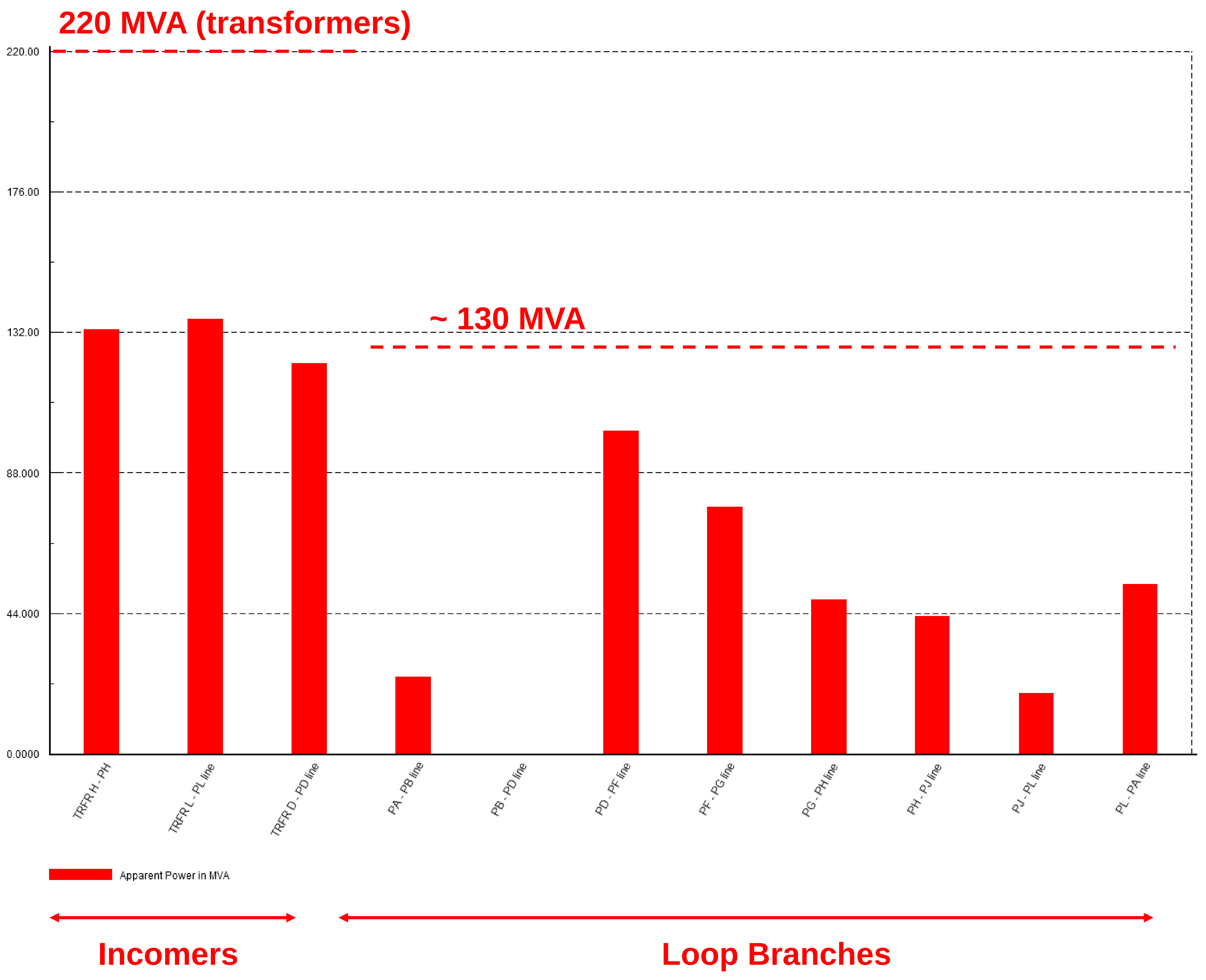




Load Flow Simulations

FCC-ee ttbar





Load Flow Simulations

FCC-ee H (n-1) → ttbar

Load Flow Simulations

Main outcomes

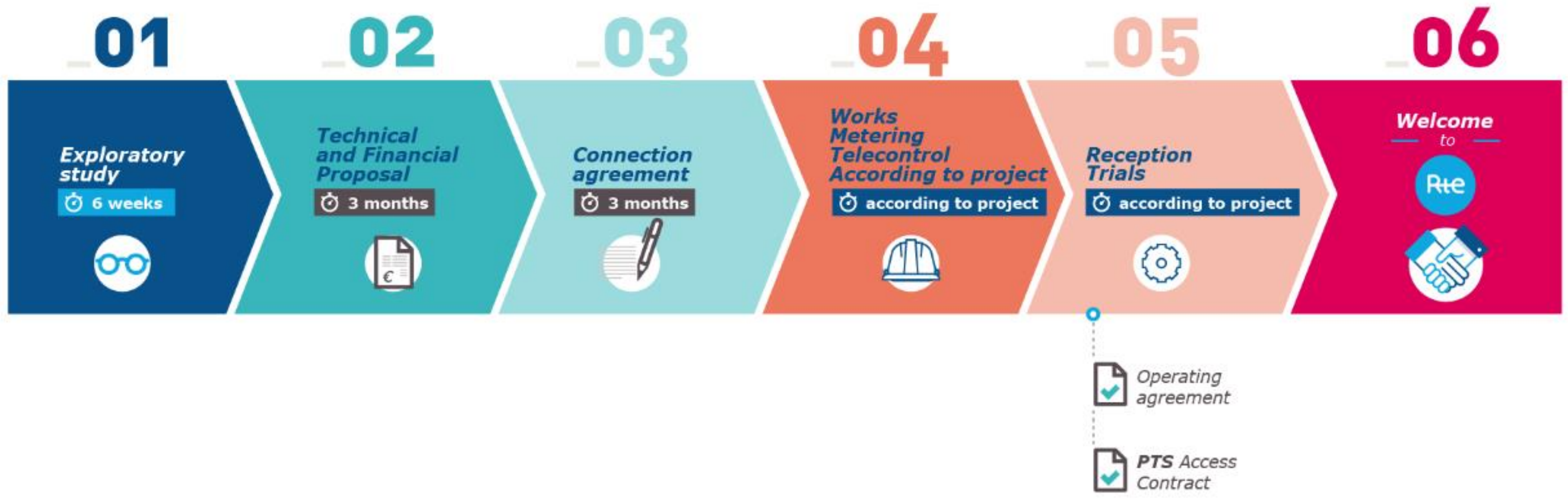
- Target sizing criteria: FCC-ee H + FCC-ee ttbar **(n-1)**:
  - Run possible if one connection point or one branch of the loop is lost
- **Main outcomes**:
  - Confirmation of the baseline for connections: n. 3 200 MW incomers, n. 3 220 MVA 400/132 kV transformers
  - Both open and closed loop operations possible
  - Identification of worst case scenario for branches in closed loop (approx. 130 MVA)

  → n-1 respected
  - Open loop cannot easily respect all n-1 scenarios (important oversizing required)
  - Closed loop operation **ideal** in terms of power balance and reliability, **but to be confirmed with RTE**
  - From H to ttbar: **possible staging** for 400/132 kV substations procurement and construction
- The sizing scenarios for each 132 kV loop branch changes → Possible tuning (**optimization**) of cross section
- Scenarios at **lower capability** can be explored (less availability, bigger MTTR)
- **Renouncing to the loop is possible:**
  - Lower investment
  - Lower reliability
  - Local MV backup power providers required for basic operations of each point

RTE grid connections – Procedure and Timeline

Feedbacks from RTE after first approach

- The overall power demands justifies a connection to RTE 400 kV (or alternatively 225 kV) grid
- Request of connection (source: RTE website):

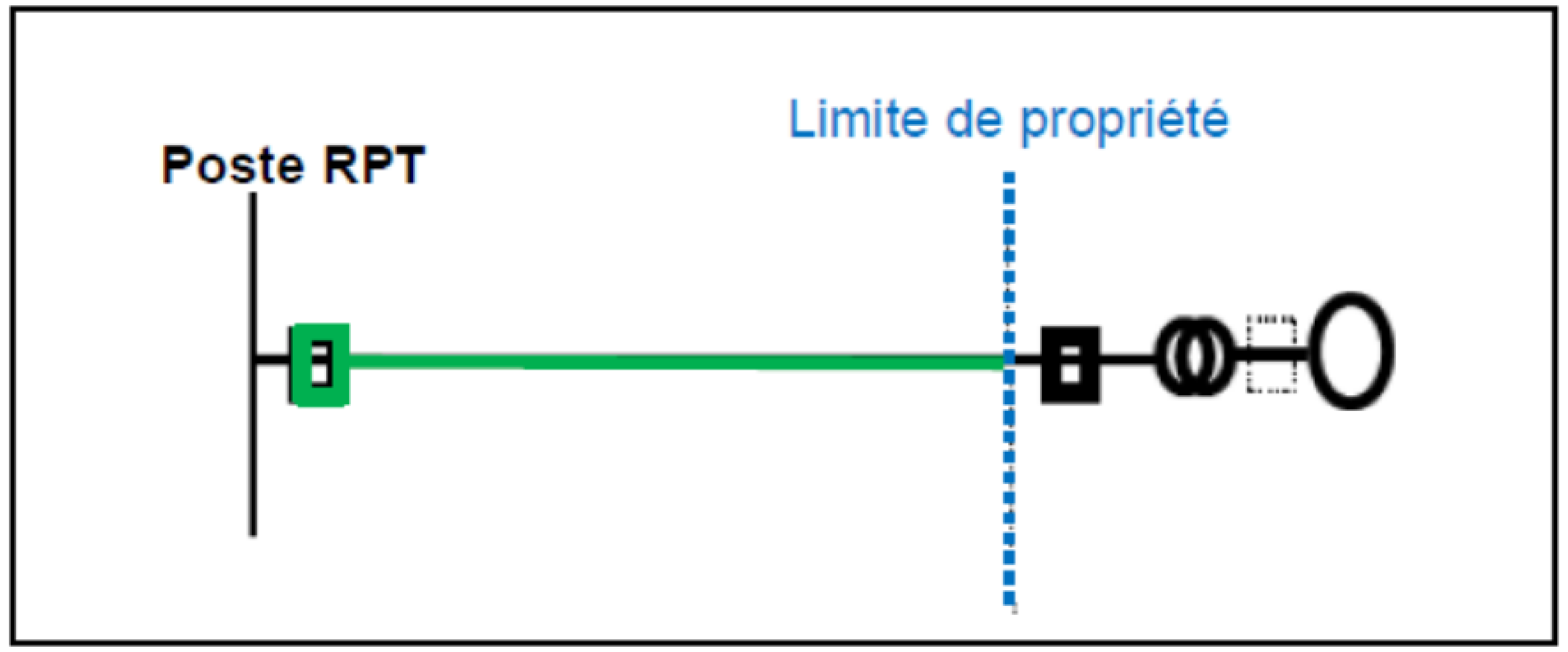


- *The first step (exploratory study) is free of charge and not binding. Data Collection Sheet available online.*
- *The further study and execution phases need investment and commitment from both parties*
- *The technical solution includes upgrade to RTE upstream infrastructure where required*

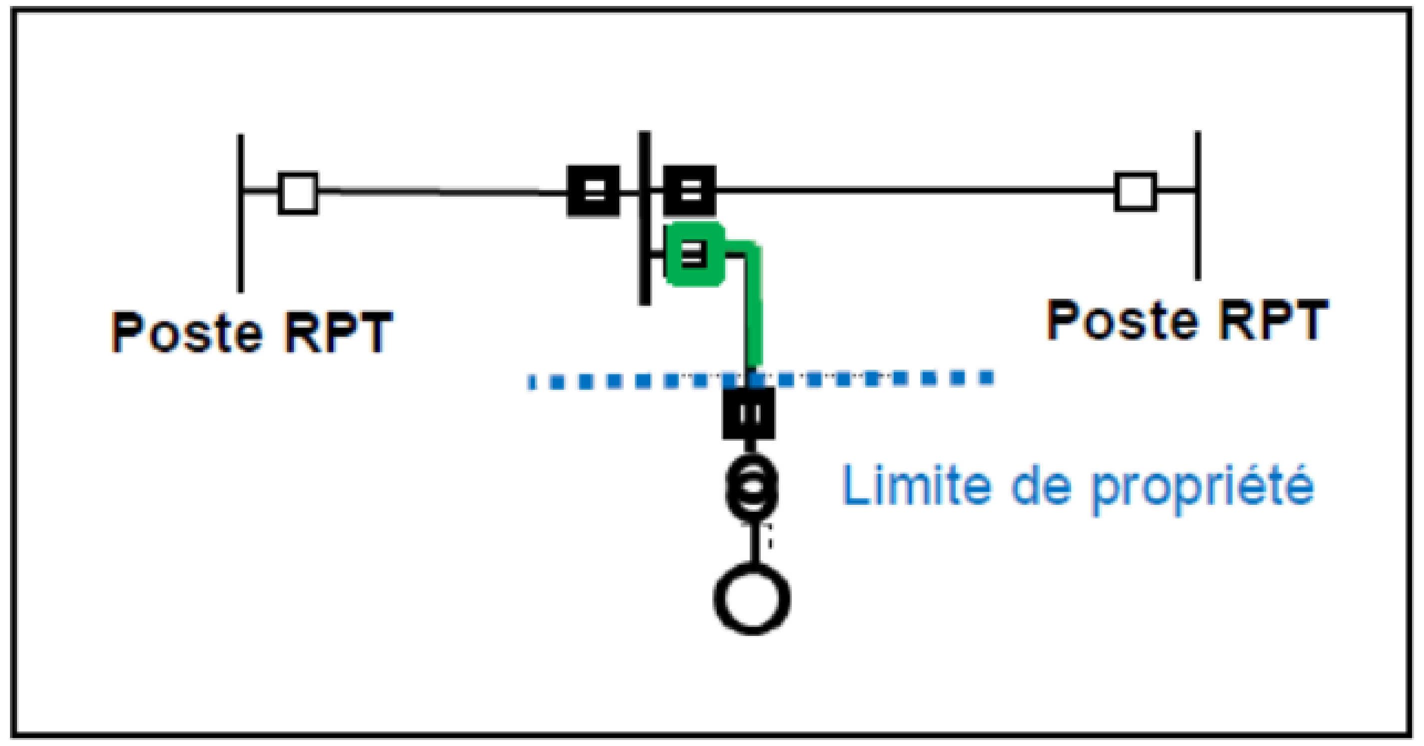
- Technical and Financial Proposal (RTE): up to 6-9 months of preparation for FCC
- From approval of TFP to Commercial Operation: **approximately 10 years or more**

RTE grid connections – Technical Options

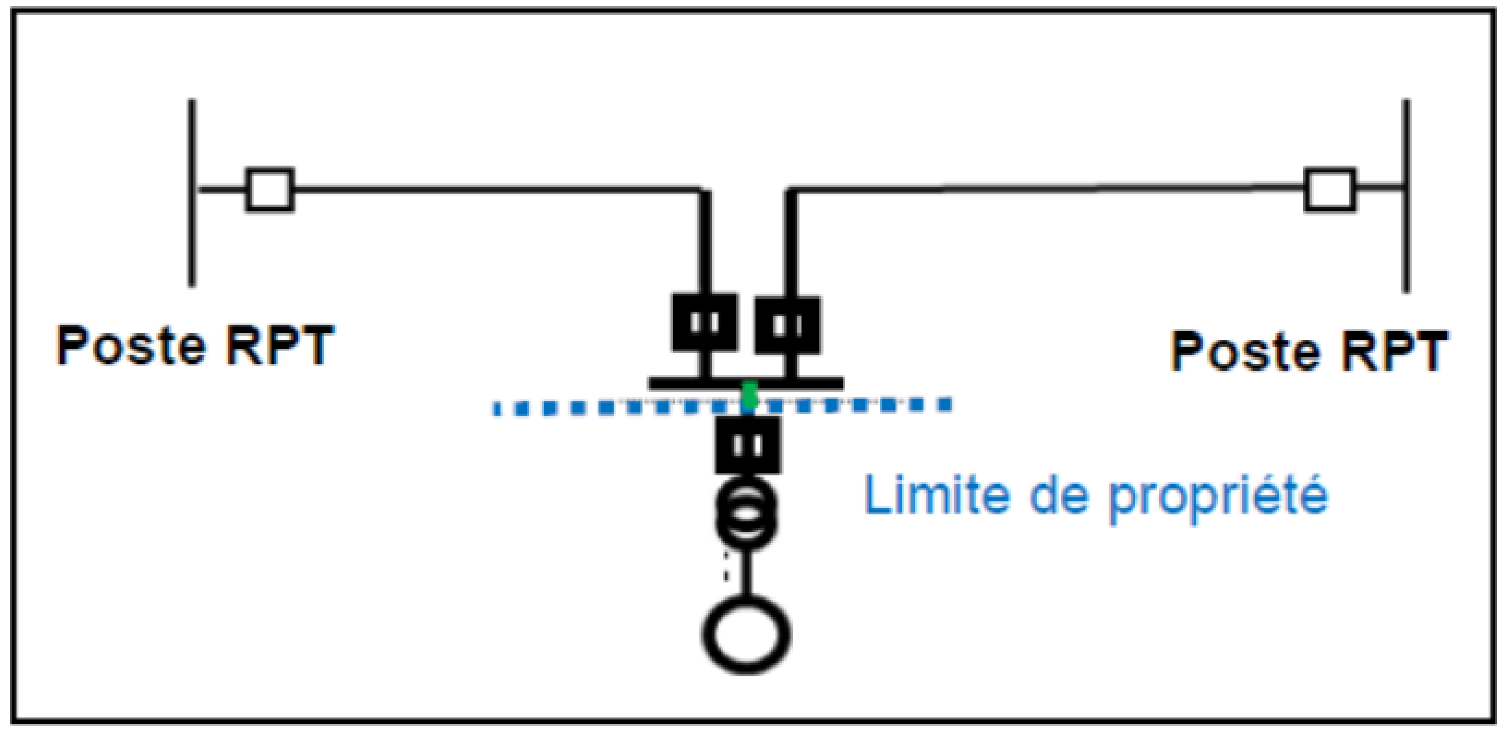
Connections to RTE: possible solutions (source: <u>RTE procedure for connection request</u>)



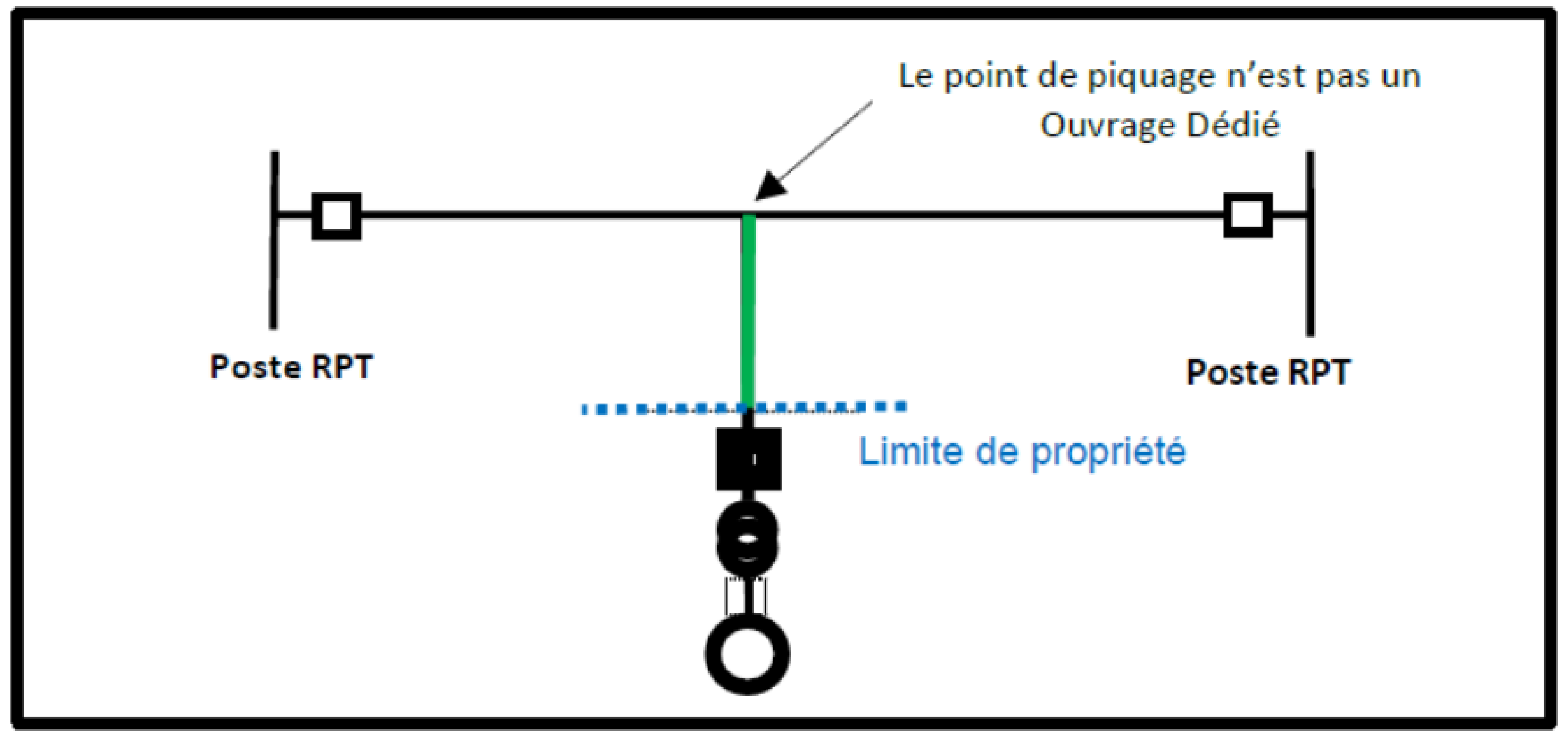
SCHEMA 1 : Raccordement sur un poste de RPT par une liaison intégrée au RPT



SCHEMA 2 : Raccordement en coupure sur une liaison du RPT au niveau de l'Installation



SCHEMA 3 : Raccordement par une liaison et un poste en coupure sur une liaison existante



SCHEMA 4 : Raccordement en piquage sur une liaison existante

RTE Grid connection - Proposal

- Three connection points
- Power demand per each connection: **200 MW**

- **PH and PL– 1st and 2nd connections (RF points)**
  - Proximity to 400 kV lines (~1.5 km)
  - Proximity and 225 kV line (~1.2 km)
  - Proximity to 225 kV substation (~3.2 km)
- **PD or PF –3rd connection (PD preferred, equidistant from PH and PL)**
  - Proximity to 400 kV substation (~5 km)
  - Proximity to 225 kV line (~3 km)

- **Check the allowed internal operations**

Very promising options for the technical feasibility

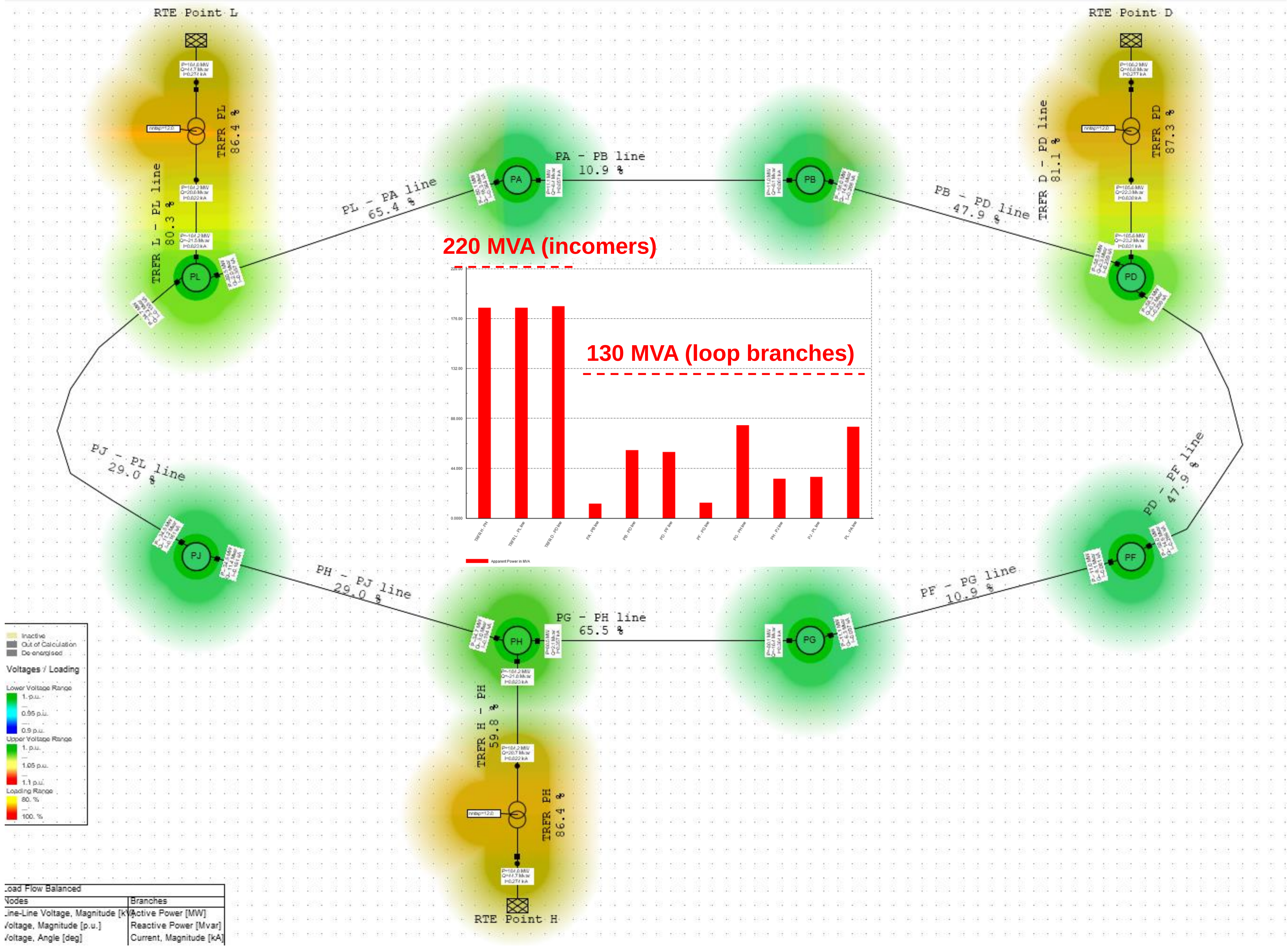
Exploratory study to be launched as soon as possible:

- **Available capability of RTE**
- **Open/close internal loop operations**
- **Ancillary services for grid stability ?**

Moving Forward – Horizon FCC-hh

Qualitative assessment of FCC-hh case:

- Preliminary and simplified load distribution
- Target load: **556 MW** (FCC Week 2018)
- Technical solution for FCC-ee **compatible** with FCC-hh requirement in RUN
- The internal 132 kV ring allows to balance the transmission **even with the new load profile** without further integrations
- n-1 scenario **would not** allow RUN mode
- At distribution level (36/0.4 kV) the installed base will **drastically change**:
  - For FCC-ee RF points **important difference**: re-work probably needed
  - → Possibility to re-use part of the equipment if the life cycle compatible
  - In all other points: possible staging from FCC-ee to FCC-hh



Conclusions

Status and challenges

- Baseline of 2018 CDR: solid and good starting point for the new layout
- Proposed HV network: **compliant** with FCC-ee and **adapted** for the evolution to FCC-hh
- Technologies and expertise widely available to implement the proposed solution
- **Space for optimization**
- Closed loop operation: **promising**, but to be verified with RTE
- Target load based on estimations that shall be **confirmed** at the next stages of the study
- Studies still ongoing**: the presented results shall be considered preliminary**
- **Next steps:**
  - Feasibility/Impact of connections to RTE grid - Exploratory study to be launched
  - Define the minimum requirements of HV and MV network in terms of RAMS
  - Complete the analysis of network scenarios
  - Optimal sizing of HV equipment
  - Progress on the definition of the downstream MV distribution (overall underground)
  - Share/update preliminary requirements for underground integration and C&V

Conclusions

Opportunities

- Use of **GIS technology** to minimize the layout oh HV substations
- **Staging** (if compliant with FCC reliability and availability requirements):
  - 400/132 kV substations
  - Downstream electrical equipment
  - 132 kV loop
- **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
- Provision of ancillary services for RTE grid stability (voltage and frequency regulation)
- 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 DC powering:
Wednesday 1st June at 12:00
“Power Converters R&D – From DC Distribution to Energy Storage System" from Davide Aguglia

Thank you for your attention