ESS Klystron Modulator Requirements

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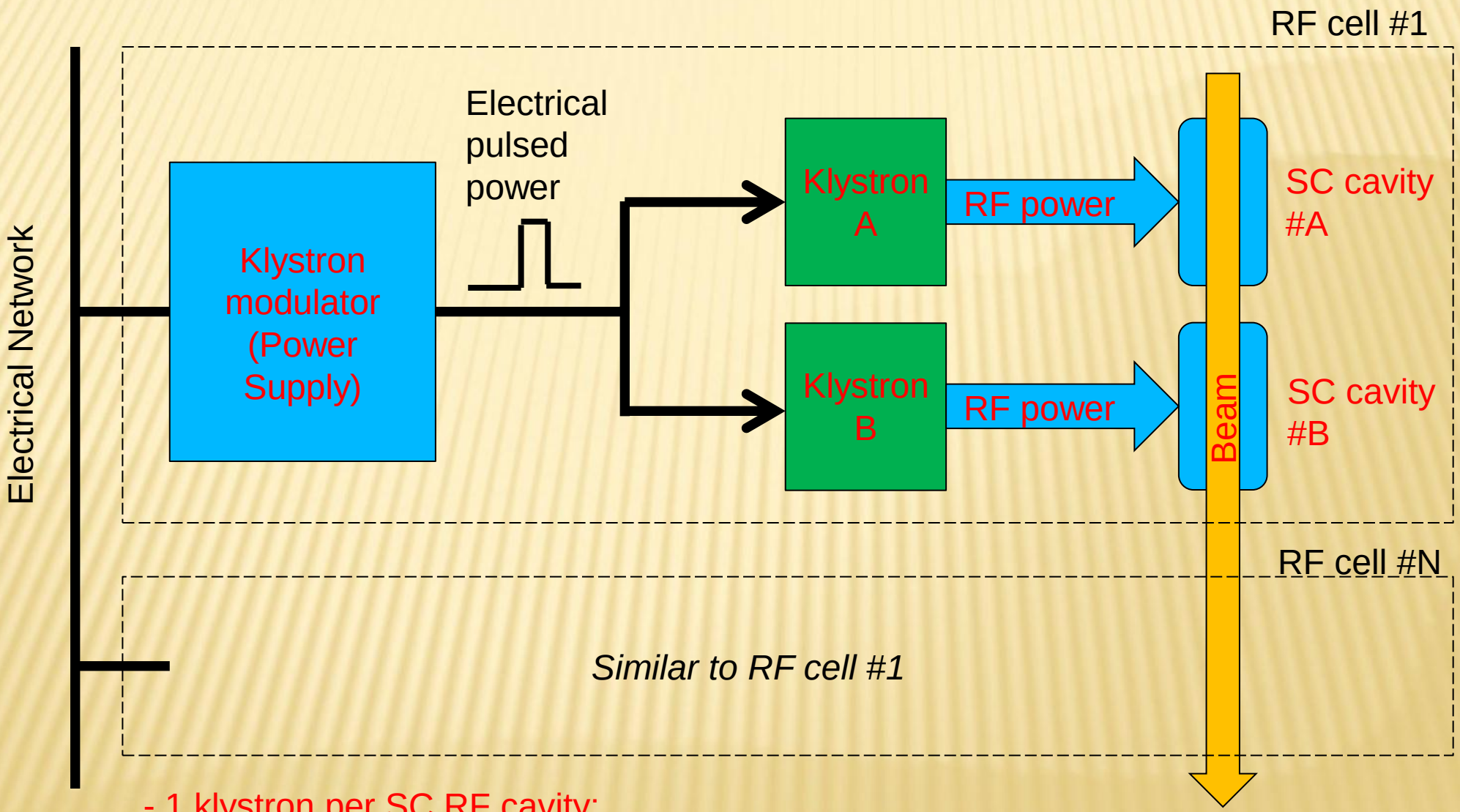
Summary

1.- RF power profile of the ESS Linac

2.- Klystron modulator ratings and parameters

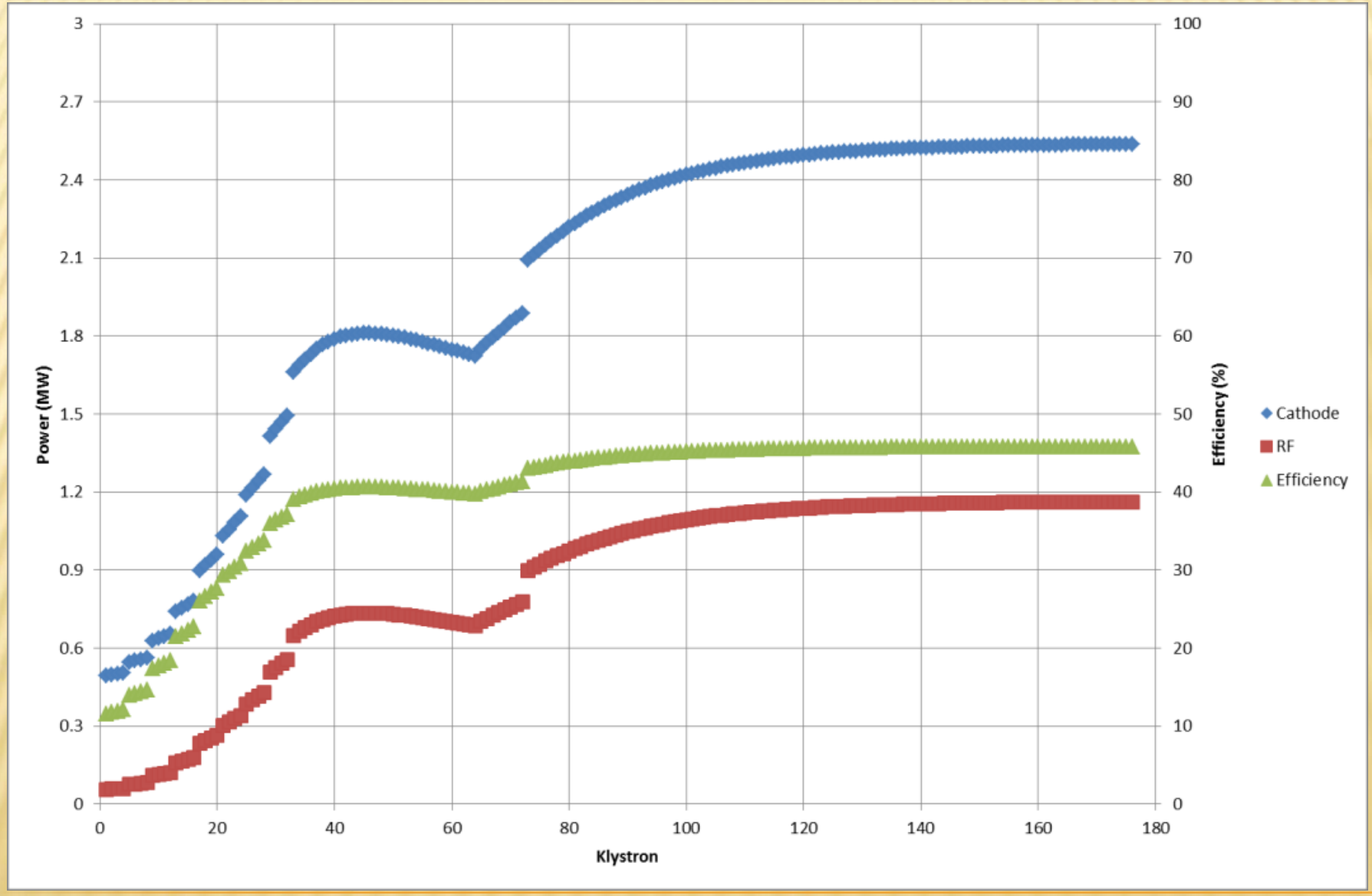
3.- Particular requirements and constraints

Klystron's powering scheme



- 1 klystron per SC RF cavity;
- 1 modulator feeds 2 klystrons in parallel (exception RFQ – 1 klystron);

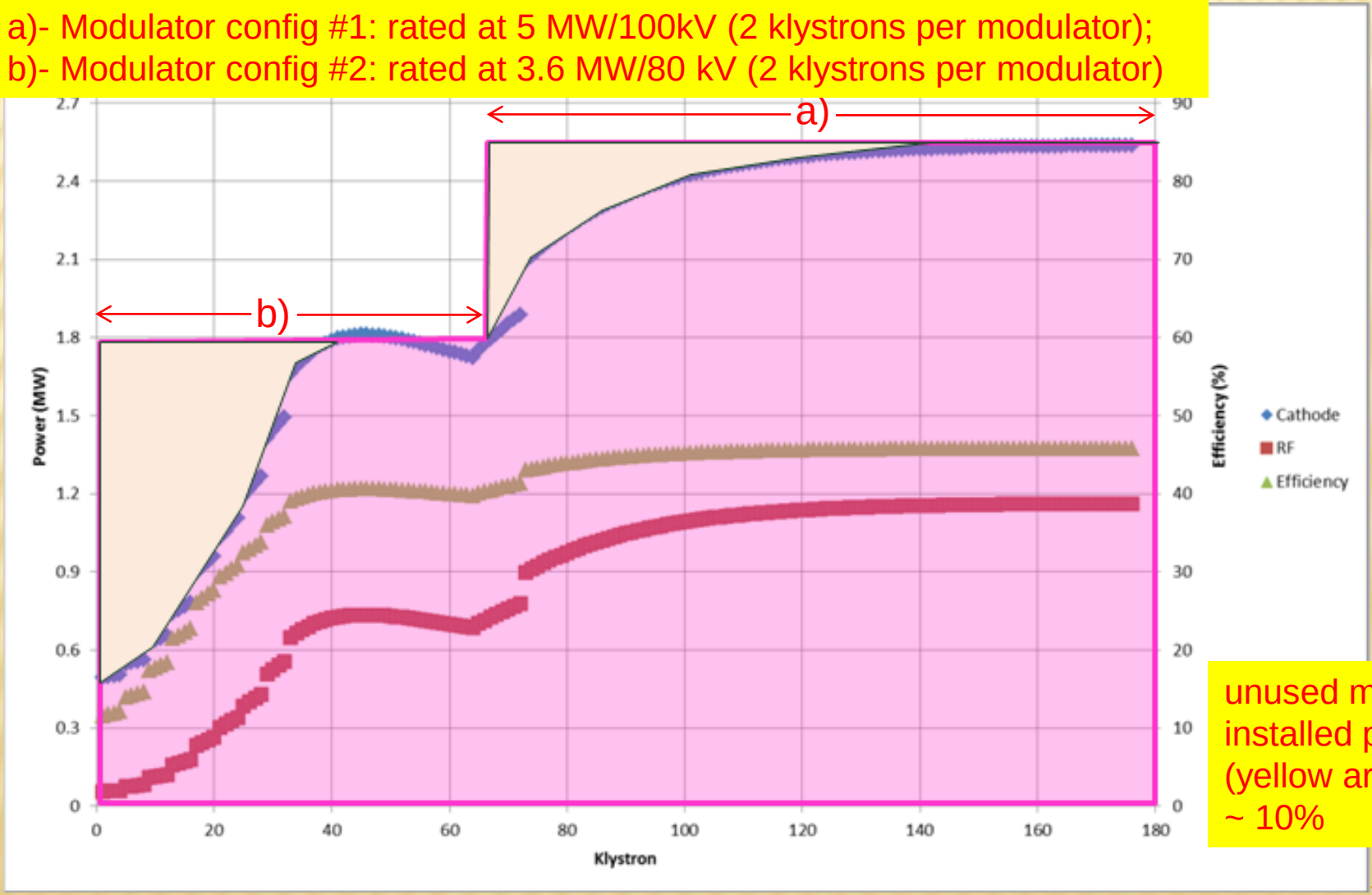
RF power profile of the ESS Linac



Adapting the modulator's installed power to the RF power profile

A single type of klystron is foreseen for the whole Linac;
A single type / topology of klystron modulator is foreseen, however deployed in two different configurations:

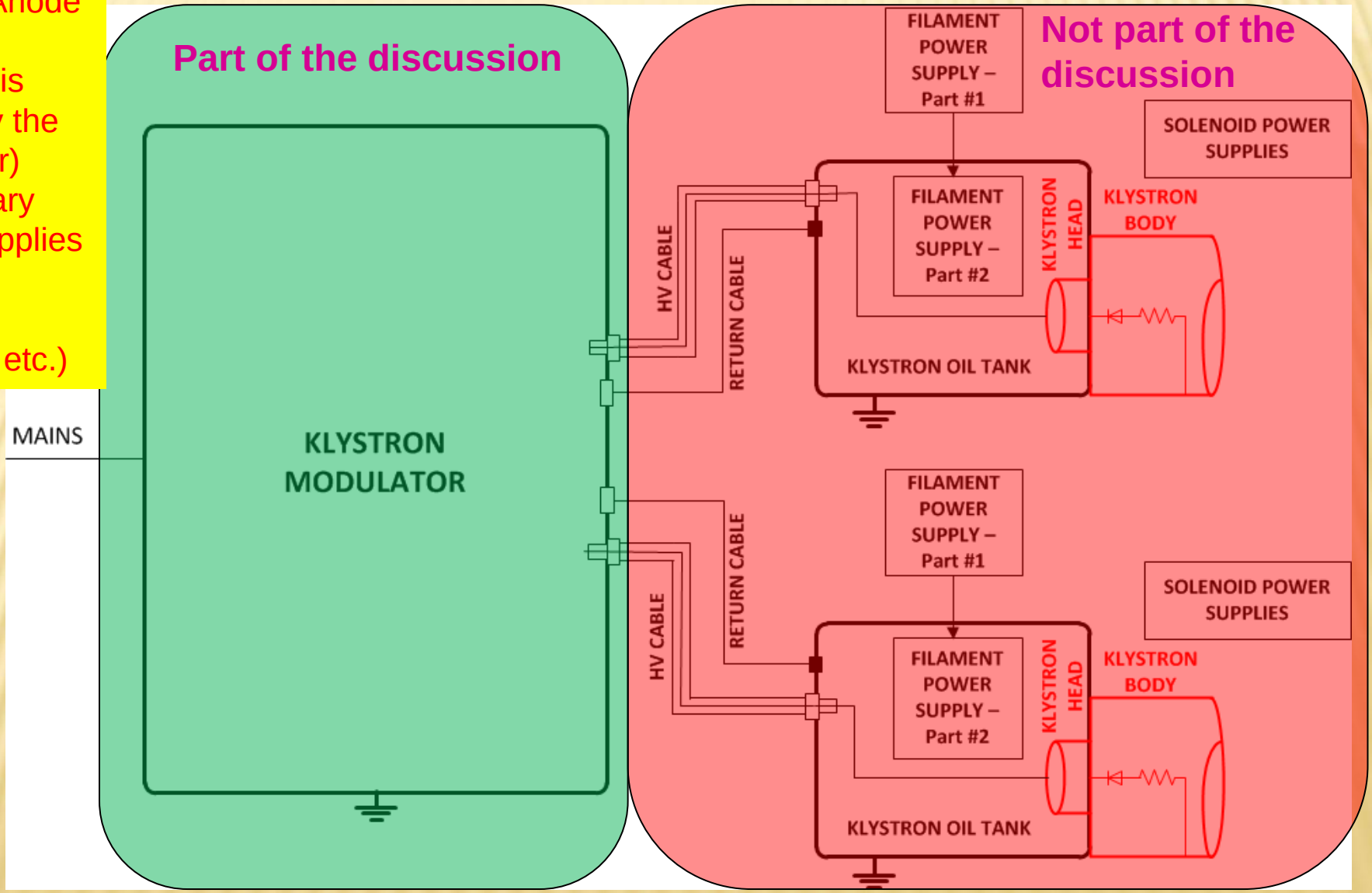
a)- Modulator config #1: rated at 5 MW/100kV (2 klystrons per modulator);
b)- Modulator config #2: rated at 3.6 MW/80 kV (2 klystrons per modulator)



unused modulators' installed power (yellow area / rose area): ~ 10%

What is meant by « klystron modulator » ?

- No Mod Anode klystrons (cathode is pulsed by the modulator)
- No auxiliary power supplies included (filament, solenoid, etc.)



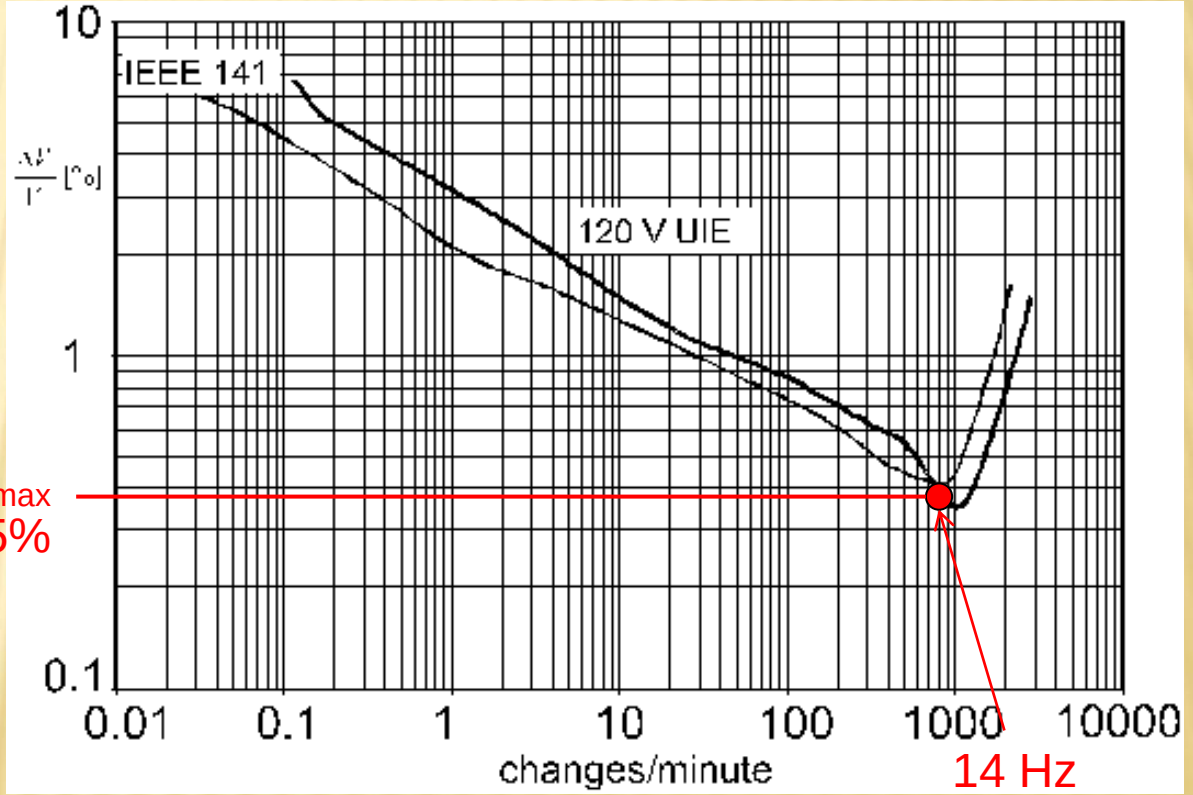
Klystron modulator's ratings and parameters

		Config #1	Config #2
Pulse voltage	U_k	100 kV	80 kV
Pulse current	I_k	50 A	45 A
Pulse length (@50% amplitude) *(adjustable off-line from 15% to 100%)*	λ	3.5 ms	
Max. rise/fall times (0-99% / 100%-10%)	T_r / T_f	190 µs	
Usefull flat-top duration	*Ftd*	3.31 ms	
Pulse Repetition Rate	*PRR*	14 Hz	
Voltage pulse flat-top « quality » *(within the usefull flat-top duration)*		droop (f < 0.3 kHz): 1% pk-pk of U_k 0.3 kHz<f<1 kHz: 0.3% pk-pk of U_k 1 kHz<f<100 kHz: 0.1% pk-pk of U_k 0.1 MHz<f<0.3 MHz: 0.3% pk-pk of U_k 0.3 MHz<f: 1% pk-pk of U_k	
Pulse-to-pulse flat-top reproducibility	*PPRep*	0.1% pk-pk of U_k	
Maximal arcing energy (50V arc voltage)	E_{arc}	10 J	

Particular requirements and constraints

1. Grid power quality

- EMC (conducted noise, immunity & susceptibility)
- Current harmonic distortion (depends on the capacitor charger topology)
- Flicker (depends on the capacitor charger topology & on the charging control scheme)
  - Flicker standards (low voltage public grids)



Particular requirements and constraints

2.- Large quantities required:

- 64 units of 300kVA + 36 units of 215kVA = 27 MVA installed average power on klystron modulators;

3.- High level of technical complexity:

- Systematic approach: development, prototyping, validation, pre-series production, series production;

4.- Maintenance and operation over a long lifetime span (25 years):

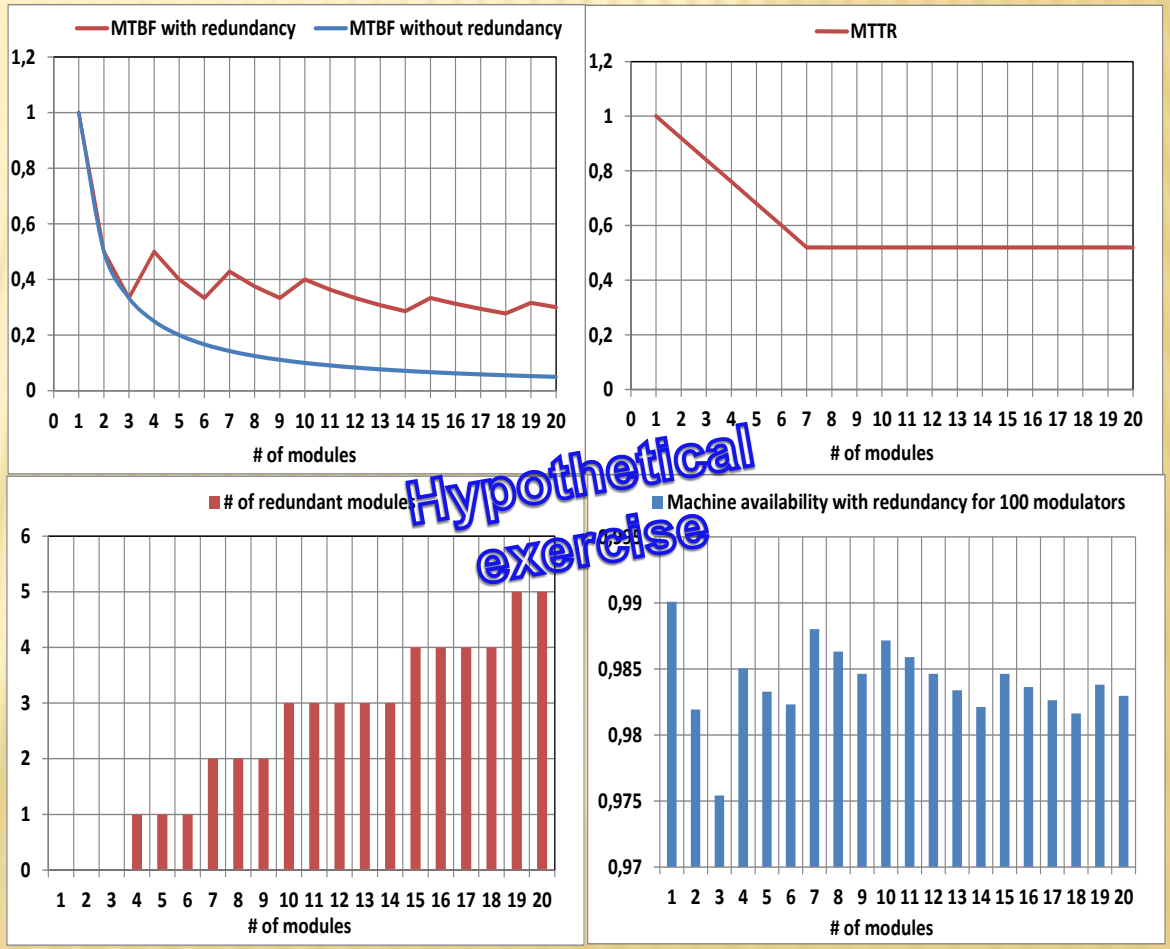
- Requires in depth technical knowledge of the systems and training of personnel (engineers, technicians);
- Ease of operation and maintenance are critical to achieve high levels of availability (no crane available in the gallery; most repairs “in situ”);
- Total availability (99%), individual reliability (MTBF>70.000h) and maintainability/reparability (MTTR<5h). Shall be accounted for from the earlier design stage;

Availability versus modularity

- Modularity: - allows for redundancy
  - facilitates reparability (decreases MTTR)

Availability = MTBF / (MTBF + MTTR)

Machine availability versus modulators' modularity



Monolithic (1 module) design:

- Reliability: MTBF = 70.000 hours;
- Repairability: MTTR = 5 hours;

Particular requirements and constraints

5.- Commercial constraints:

- Big contracts. Not many companies in the field. How many companies should be involved?
- European rules for tendering. Legal aspects;
- After sales support and quality assurance;
- Contract awarding policy (ex. rule: no contract **should** be awarded to a company having a turn-over (average of the last 3 years) inferior to ~3x of the contract value divided by the number of years of contract duration.

  Ex: contract of 40 M€ for a duration of 4 years → average turn-over: > 30 M€

6.- Time constraints:

- Prototypes ready by end 2014;
- Prototypes validated by mid 2015;
- Series production (~100 units) and delivery to ESS completed by mid 2018;
- Installation and commissioning completed by April 2019;

Inauguration day: June 2019.

Thank you for your attention !

Questions ?