LINAC4 Quadrupole Power Converters

TE-EPC

J.M. CRAVERO

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Requirements

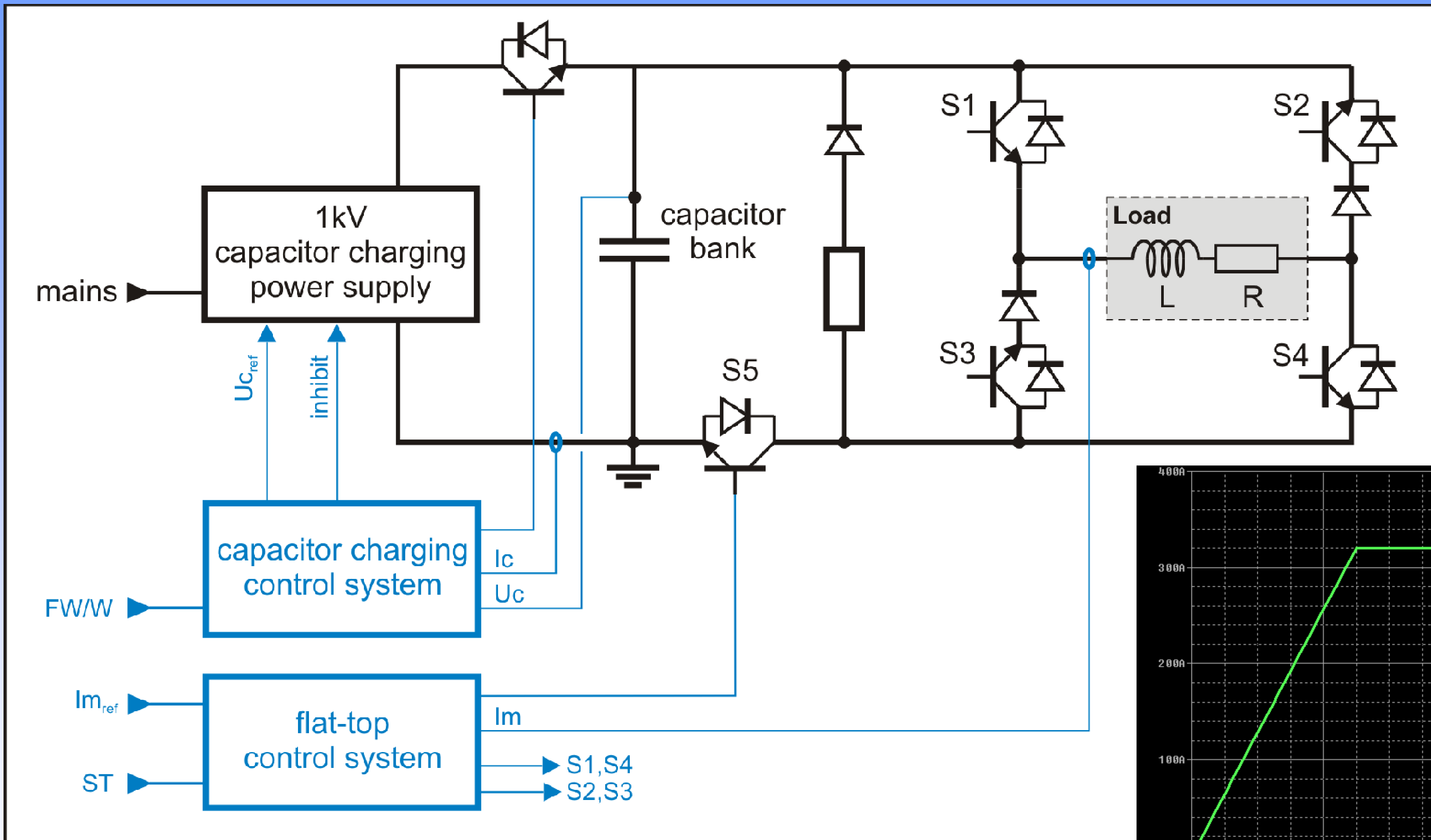
- **Requirements summary**

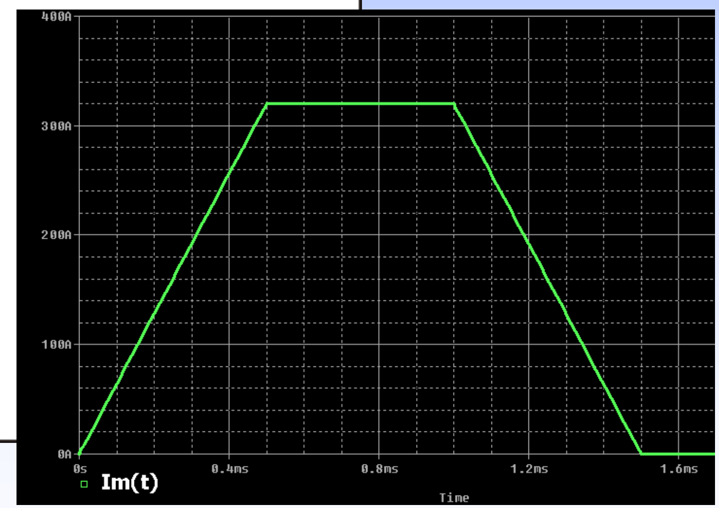
	application	DTL-CCDTL-PIMS	DTL-CCDTL-PIMS	PSB - TL
magnet	magnet number (serial)	1	2	
	maximum operating current	100 A	100 A	
	inductance	10.8 mH	21.6 mH	
	resistance	0.38 Ω	0.76 Ω	
cable +filter	inductance	0.12 mH	0.18 mH	0.09 mH
	resistance	0.5 Ω	0.6 Ω	0.35 Ω
power converter	power converter type	Maxidiscap III	Maxidiscap III	Maxidiscap III
	precision during flat-top	~1000 ppm	~1000 ppm	~1000 ppm
	operating voltage	600 V	900 V	
	flat top duration	2 ms	2 ms	1 ms
	repetition rate	2 Hz	2 Hz	1.1 Hz
	quantity (workpackage)	23	0	16

- PSB-TL quads parameters are under study
- DC cabling has been considered but the cable definition is not done
- an output filter has been added to suppress overvoltages on the load due to cable length
- a flat-top of 2ms duration has been considered for the converter design
- final quantities are still under discussion

Maxidiscap Topology

- **Converter topology**



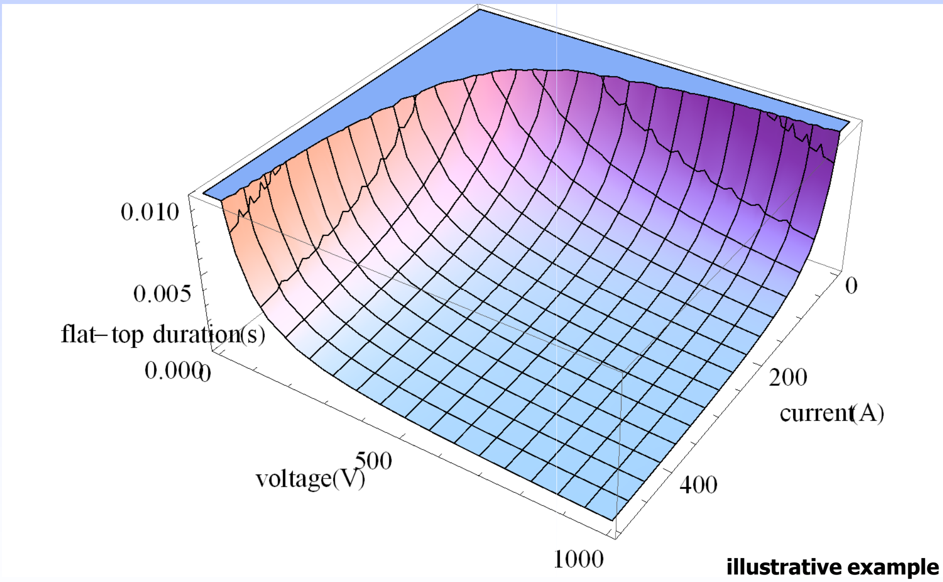


- S1, S2, S3, S4 are used to ramp the current (up or down)
- S5 is used in linear mode to produce the flat-top

Maxidiscap Limitations

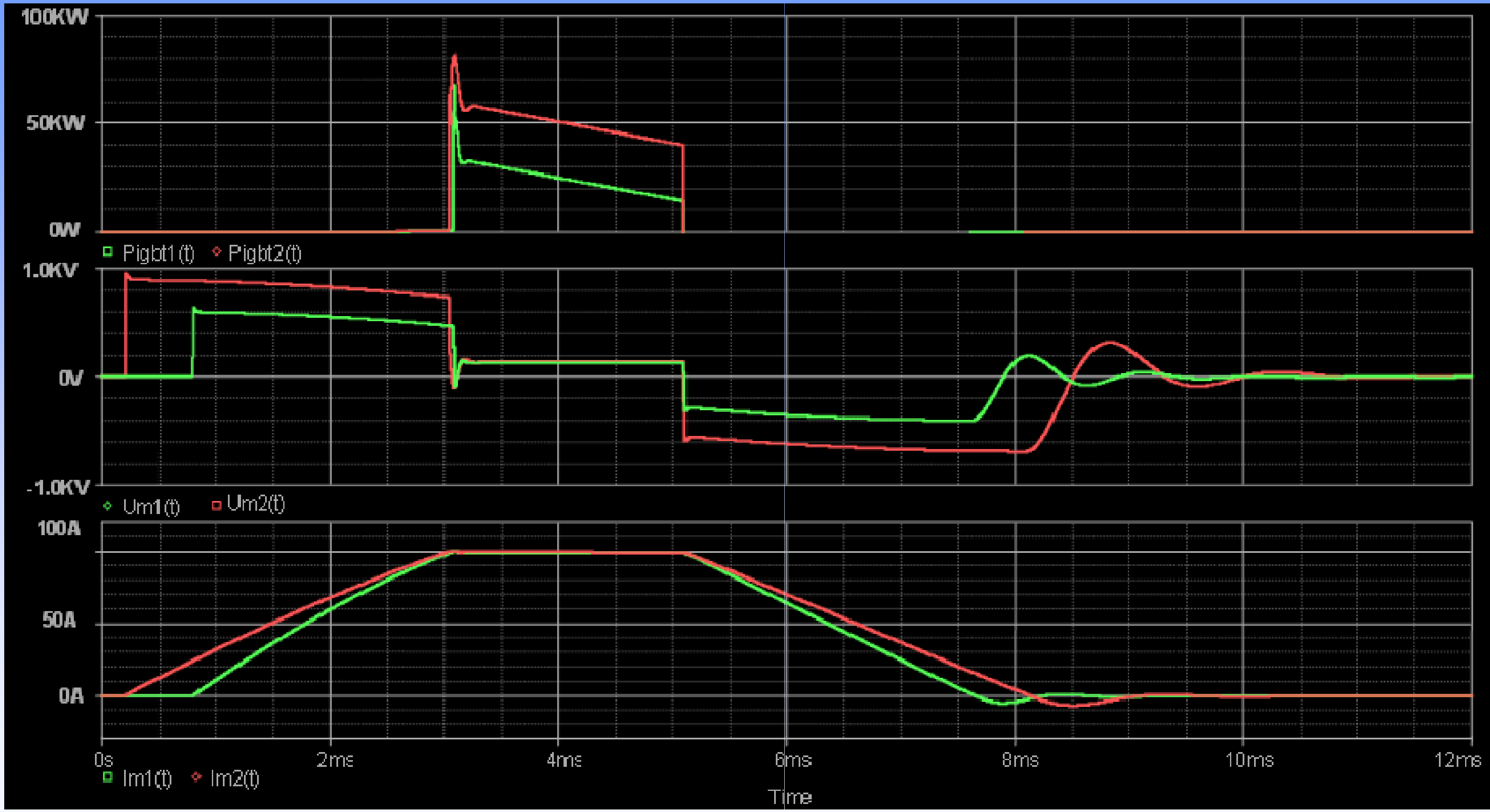
- **Maxidiscap converters are pulsed power converter with a linear stage, some limitations are inherent to this topology**
  - the average power that can be dissipated in the linear stage is limited by the cooling
  - the power dissipated in the linear stage leads to thermal cycling in the IGBT and may imply limited lifetime expectancy for the device
  - the energy stored in the capacitor bank that is transfered to the load during the discharge is limited

➔ the maximum flat-top duration is a function of the maximum operating current, the charging voltage and the load parameters.



Simulations, junction temperature and expected lifetime

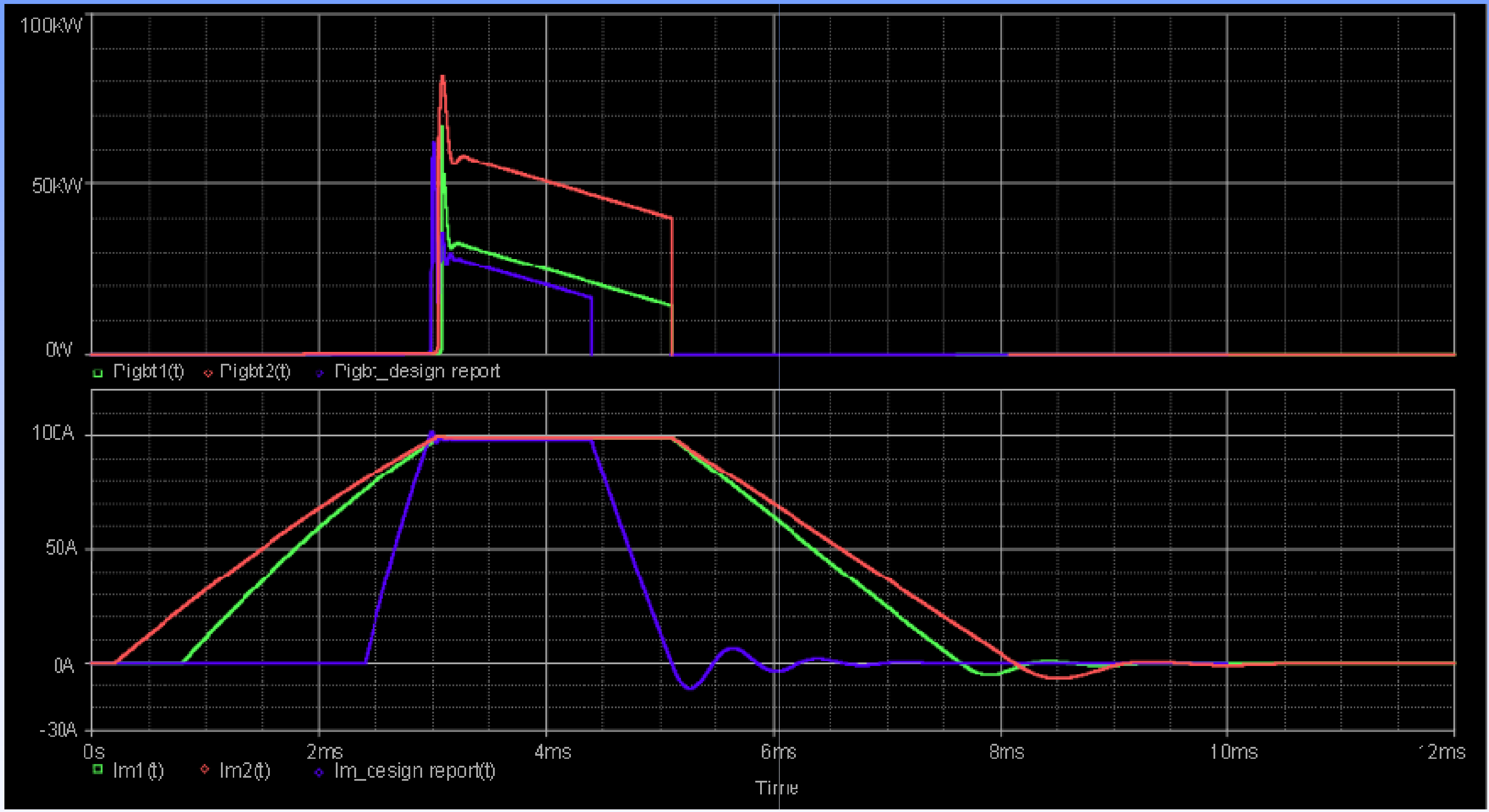
- **DTL-CCDTL-PIMS quadrupoles : waveforms with 2ms flat-top**



- green ➔ load = 1 magnet – Uc=600V ➔
- red ➔ load = 2 magnets serially connected – Uc=900V

Simulations, junction temperature and expected lifetime

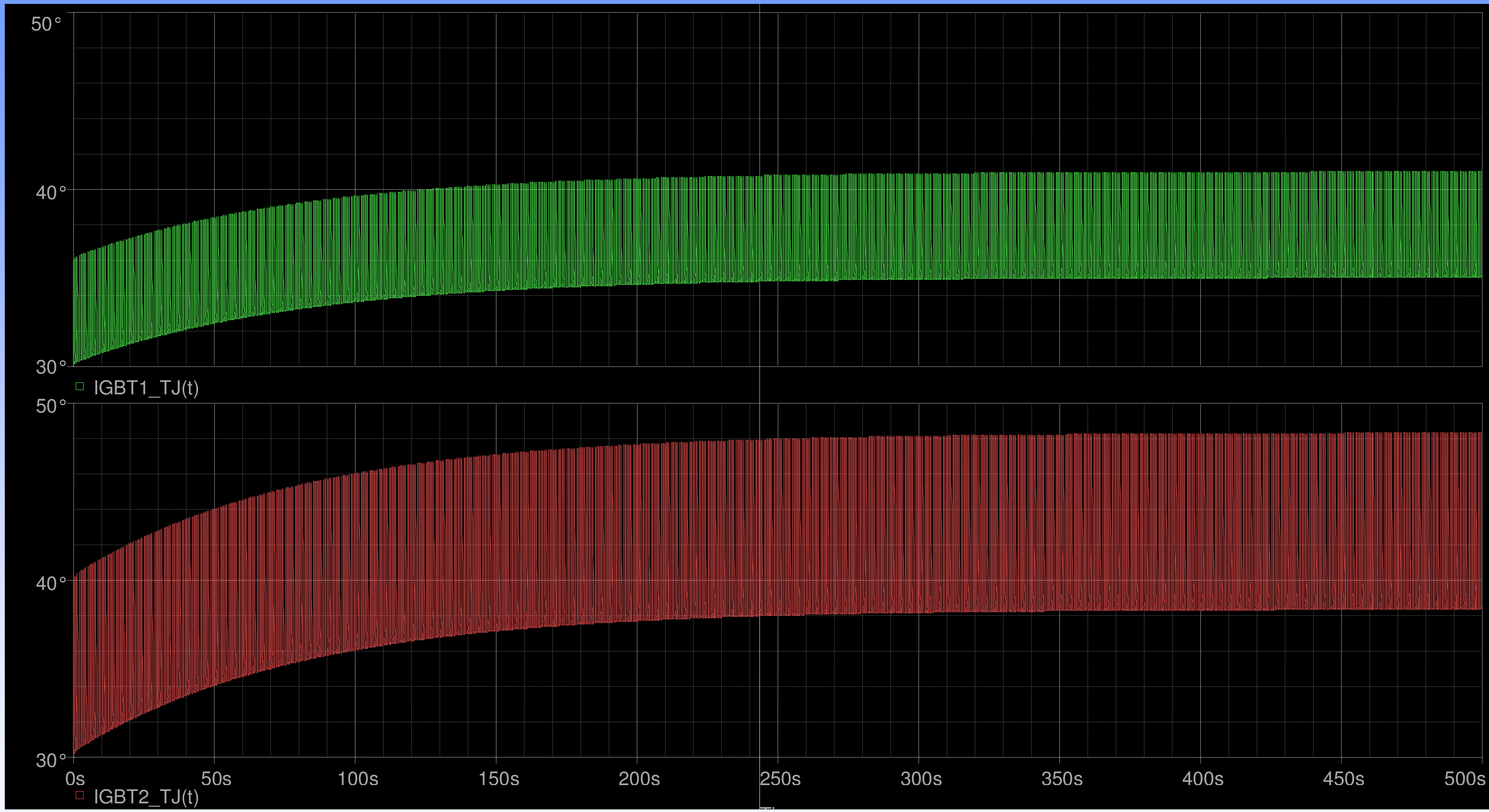
- **DTL-CCDTL-PIMS quadrupoles : change from design report**



- green ➔ 1 magnet (actual) – Uc=600V – flat-top duration=2ms
- red ➔ 2 magnets in serie (actual) – Uc=900V – flat-top duration=2ms
- blue ➔ 1 magnet (design report) – Uc=400V – flat-top duration=1.4ms

IGBT junction temperature and expected lifetime

- **DTL-CCDTL-PIMS: IGBT junction temperature**



- green (1 magnet – 2ms flat-top) ➔ΔTj = 6° - MaxTj= 41°
- red (2 magnets – 2ms flat-top) ➔ ΔTj = 10° - MaxTj= 49°

➔ with such values, thermal cycling has not effect on lifetime expectancy

Technical Design Summary

	application	DTL-CCDTL-PIMS	DTL-CCDTL-PIMS	PSB - TL
magnet	magnet number (serial)	1	2	
	maximum operating current	100 A	100 A	
	inductance	10.8 mH	21.6 mH	
	resistance	0.38 Ω	0.76 Ω	
cable +filter	inductance	0.12 mH	0.18 mH	0.09 mH
	resistance	0.5 Ω	0.6 Ω	0.35 Ω
power converter	power converter type	Maxidiscap III	Maxidiscap III	Maxidiscap III
	operating voltage	600 V	900 V	
	flat top duration	2 ms	2 ms	1 ms
	repetition rate	2 Hz	2 Hz	1.1 Hz
	quantity (workpackage)	23	0	16
output current and power	rise time	2.2 ms	2.8 ms	
	di/dt	45.5 kA/s	35.7 kA/s	
	flat-top	2 ms	2 ms	
	fall time	2.6 ms	3.2 ms	
	P peak flat-top	40.0 kW	60.0 kW	
	Max. Junction temp.	41 º	49 º	
	Delta TJ simulated (per pulse)	6 º	10 º	
	Irms (100A-2ms flat-top)	9.5 A	10 A	
	Pmagnet (100A-2ms flat-top)	34 W	38 W	
	Irms (80A-1.5ms flat-top)	6.9 A	7.4 A	
	Pmagnet (80A-2ms flat-top)	18 W	21 W	

- RMS values are compatible with magnet design
- TL quads : the goal is to use the same converter design for both magnets parameters

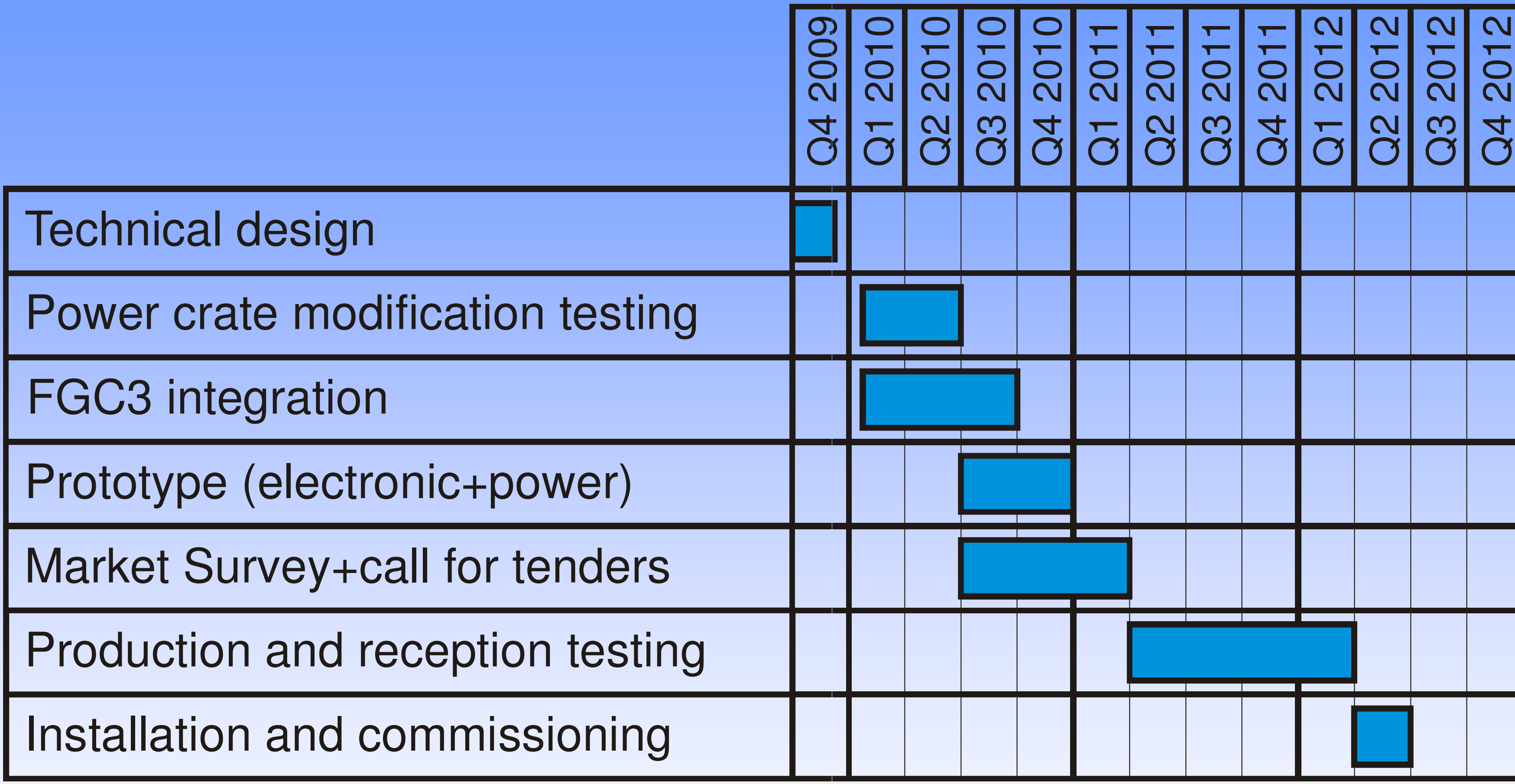
Power Converter Modifications

- **Same converters have been used in Linac II, Linac III and LEIR but some modifications are necessary to allow flat-top with extended duration**
- **Power crate**
  - **- the capacitor bank has to be increased to 1000uF**
  - **- capacitor charger replacement have to be studied**
  - **- some modifications have to be foreseen (cabling, IGBT driver , etc...)**
  - **- test with filter, cables and dummy load have to be performed**
  - **- compatibility with previous versions must be kept**
- **Electronic crate**
  - **- FGC3 integration**
  - **- flat-top control with anti-windup system has to be evaluated**

Electronic crate

Power crate

Basic Planning



- Technical design must be finished before the end of 2009, TL quads parameters have to be defined urgently.
- Final converter quantities are not needed before mid-2010

Conclusion

- **With the latest LINAC4 EM Quad design, it is possible to power 1 or 2 magnets in series by limiting the di/dt during the ramp**

- **The PSB transfer line Quads and LINAC4 Quads will use the same power converter design**

  ➔ final converter design will be done when the PSB transfer line magnet design is well advanced

- **Development and test of the Quadrupole Power Converter prototype will start early 2010, with series production in 2011**

  ➔ final quantities are required before tendering in mid-2010