

# Power Converters for Linac 4 (@ 2 Hz)

Carlos A. MARTINS

*Accelerators and Beams (AB) department  
Power Converters (PO) group*

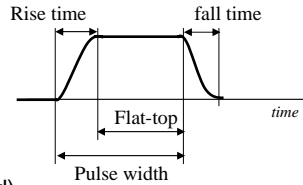
## Table of contents

1. General characteristics and overview of power converters
2. Klystron Modulators
3. Power converters for Steering magnets
4. Power converters for Quadrupole magnets
5. Power converters for transfer line Bending magnets
6. Power converters for Booster Injection Septa magnets
7. Power converters for the 3 MeV front end  
*(re-use of existing 3 MeV Test Stand converters)*
8. Installation layout in the building
9. Conclusions

# 1. General characteristics

## Pulsed converters whenever possible:

- Flat-top (precision): 1.2 ms;
- Pulse width: 1.5 ms;
- Repetition rate: 2 Hz;
- Cooling: Air (natural or forced)



## Power converter controls:

- Standard PO local controller: FGC3 (Function Generator and Controller)
- Remote controls: WorldFiP field bus based architecture

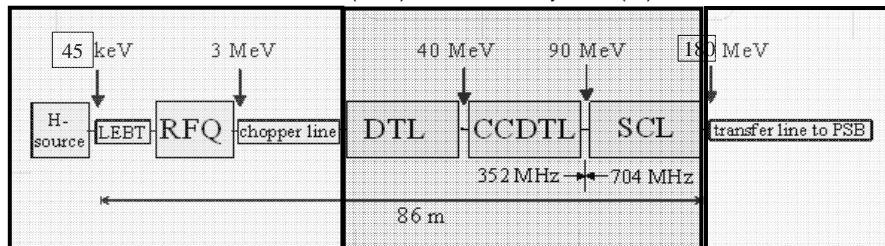
Note: For the 3 MeV Front-End power converters:  
(Linac 4 as PS Booster injector operation only)

- Flat-top: 600  $\mu$ s
- Pulse width: 800  $\mu$ s;

# 1. Power converters overview

Three main sectors in the machine:

- 3 MeV front end (0 -> 3MeV);
- Linac4 machine (3MeV -> 180MeV);
- Transfer line to PS Booster (PSB) and Booster Injection (BI)



### 3 MeV Front End power converters:

- HV DC, for H- source; (x4)
- Klystron Modulator for RFQ; (x1)
- Pulsed, for quadrupole magnet(x11)
- DC for Steering magnets; (x7)
- Pulsed, for solenoid magnets; (x2)

(x ..) – quantities without spares

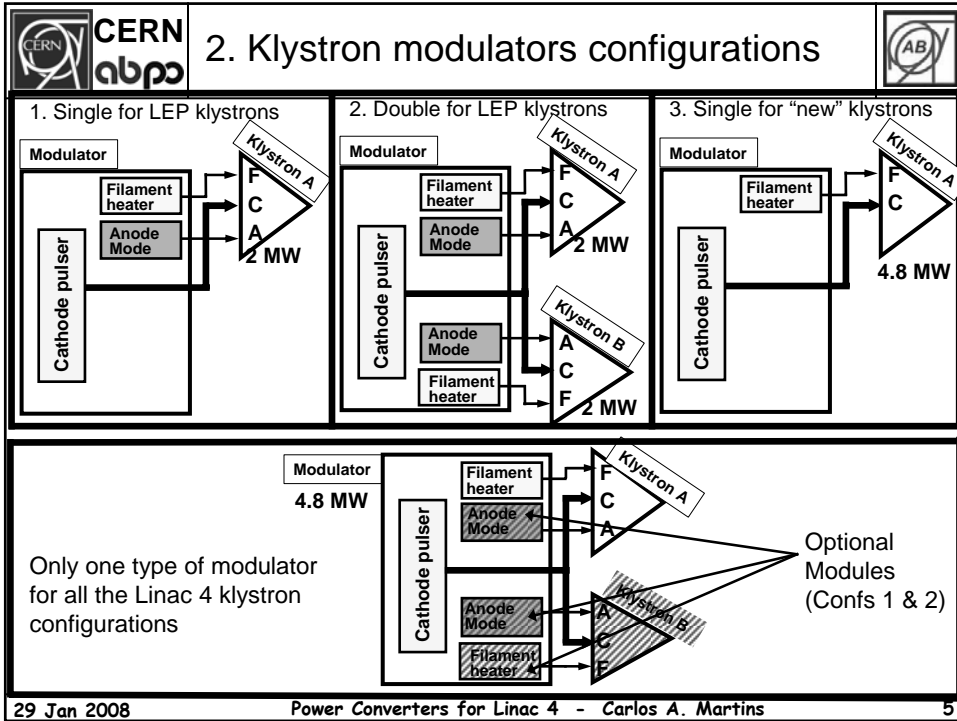
### Linac4 machine power converters:


- Klystron Modulators; (x13)
- Pulsed, for quadrupole magnets; (x23)
- Pulsed, for Steering magnets; (x30)

### Transfer Line to PSB and BI power converters:


- Pulsed, for Bending magnets; (x2)
- Pulsed, for quadrupole magnets; (x17)
- Pulsed, for Steering magnets; (x10)
- Pulsed 20kA, for BI Septa; (x3)

Total: 105 magnet power converters + 15 klystron modulators

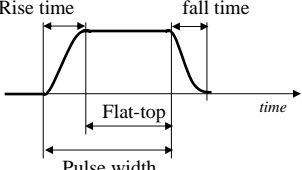




## 2. Klystron modulators parameter table



| <b><u>Cathodes power supply</u></b> |                         |
|-------------------------------------|-------------------------|
| - Pulse width:                      | 1.5ms                   |
| - Flat-top duration                 | 1.2 ms                  |
| - Precision at flat-top:            | < 1%                    |
| - HF ripple at flat-top:            | < 0.1%                  |
| - Repetition rate:                  | 2 Hz                    |
| - Nominal voltage:                  | 120kV (*)               |
| - Nominal current:                  | 2x20A (*)               |
| - Rise/fall times:                  | 150µs                   |
| - Cooling:                          | Air (natural or forced) |
| - Maximum energy in case of arc:    | < 20 J                  |



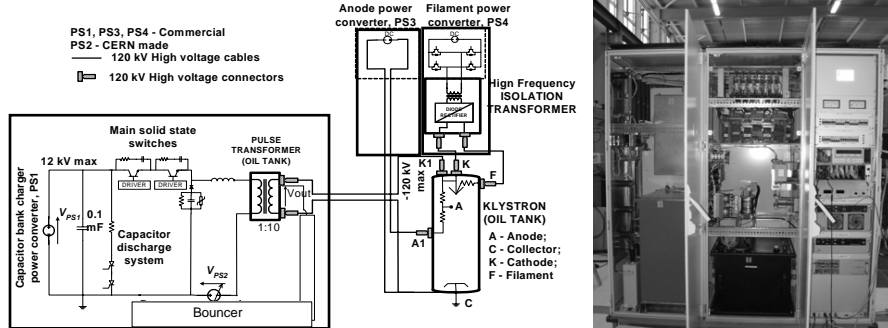
| <b><u>Anode Mode polarization power supplies</u></b> |           |
|--|-----------|
| - Stability at flat-top:                             | < 1%      |
| - HF ripple at flat-top:                             | < 0.1%    |
| - Nominal voltage to cathode :                       | 60 kV (*) |
| - Nominal current:                                   | 5 mA (*)  |

(\*) to be confirmed, taking the new klystrons design into consideration

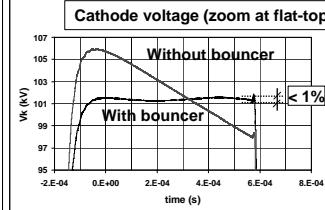
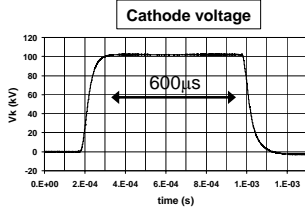
| <b><u>Filament heater power supplies</u></b> |                    |
|--|--------------------|
| - Stability and ripple:                      | < 1%               |
| - Nominal voltage:                           | 30V (*)            |
| - Nominal current:                           | 35A (*)            |
| - Floating withstand voltage to ground:      | 180kVdc for 1 min. |

29 Jan 2008
Power Converters for Linac 4 - Carlos A. Martins
6

Cathode ratings: 100 kV, 20A, pulsed 2 Hz, flat-top: 600  $\mu$ s



A global klystron supply solution:  
(Cathode, Anode, Filament) in one system

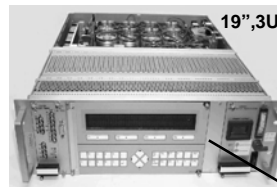


29 Jan 2008

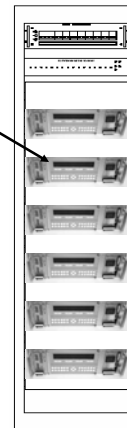
Power Converters for Linac 4 - Carlos A. Martins

7

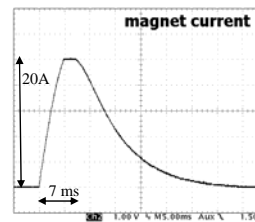
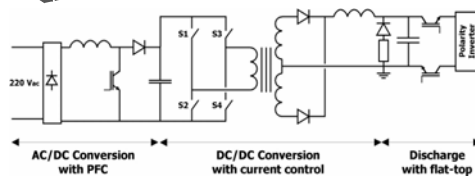
- 600V, +/-20A;
- pulsed 2Hz;
- flat-top duration: 1.2 ms;
- flat-top precision: ~1000 ppm;



6 units per rack



Standard CERN design



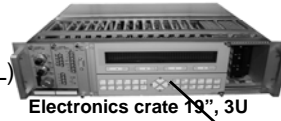
29 Jan 2008

Power Converters for Linac 4 - Carlos A. Martins

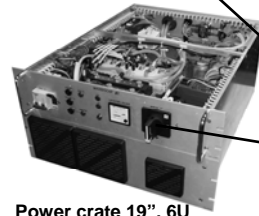
8

## 4. Power converters for quadrupole magnets

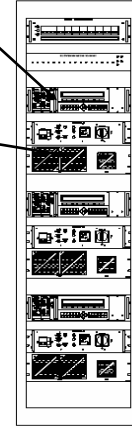
- 1 kV, 200A;
- pulsed 2 Hz;
- flat-top duration: 1.2 ms (Linac 4 machine+TL) 600 $\mu$ s (3 MeV Front End)
- flat-top precision: ~1000 ppm



3 units per rack

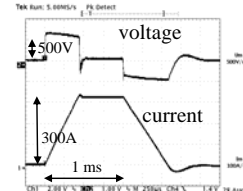
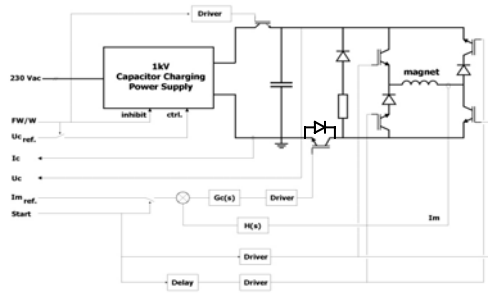


Power crate 19", 6U



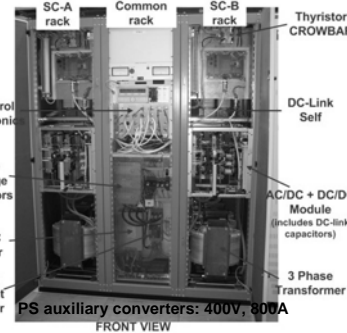
Maxidiscap

Standard CERN design



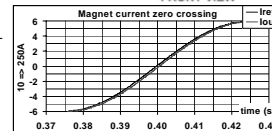
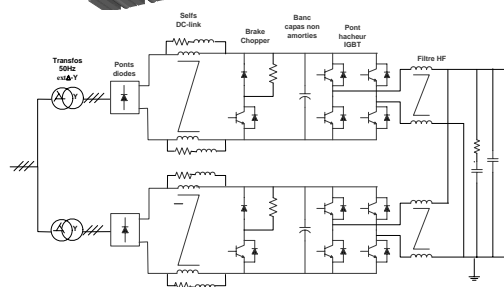
## 5. Power converters for Transfer Line Bending magnets

- 250V, 1000A;
- pulsed 2 Hz;
- flat-top duration: ~100 ms;
- precision at flat-top: ~100 ppm

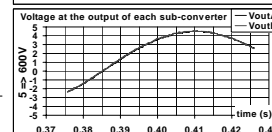


HardSwitching

Standard CERN design



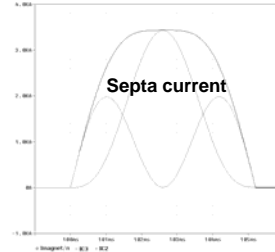
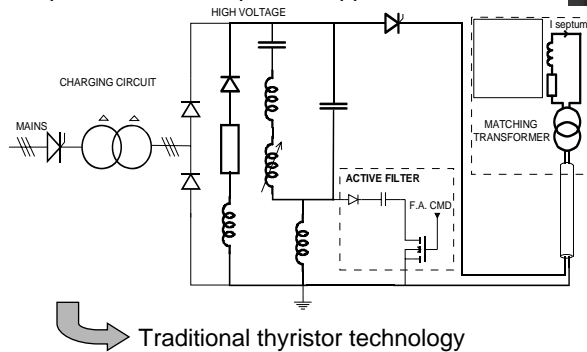
Arbitrary current function generation



## 6. Power converters for Booster Injection Septa magnets

- 300V, 20kA;
- pulsed 2 Hz;
- flat-top duration: 600 $\mu$ s;
- precision at flat-top: ~1000 ppm

High Current DisCap



Traditional thyristor technology

**New topology under study, based on new semiconductor technology, more compact and less expensive for long pulses**

## 7. Power converters for the 3 MeV Front End

- All the existing 3 MeV Test Stand converters will be re-used for the Linac 4 3-MeV Front End, except the RFQ klystron modulator
- New universal controls system to be installed: FGC 3 + WorldFip
- Flat-top is limited to 600 $\mu$ s

Existing power converters at the 3 MeV Test Stand to be refurbished

Power converters for Solenoids  
( 2kV, 2kA, 600 $\mu$ s / 2Hz )



Power converters for quadrupoles (MaxiDisCap)  
(1kV, 200A, 600 $\mu$ s/2Hz)  
+ steerers / bendings  
(35V, 20A, DC)

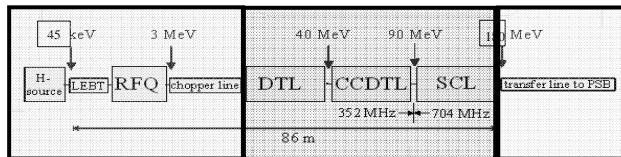


HV power converter for H- source RF amplifier  
(22 kV, 300mA, DC)



HV power converter for H- source platform  
(60 kV, 2mA, DC)



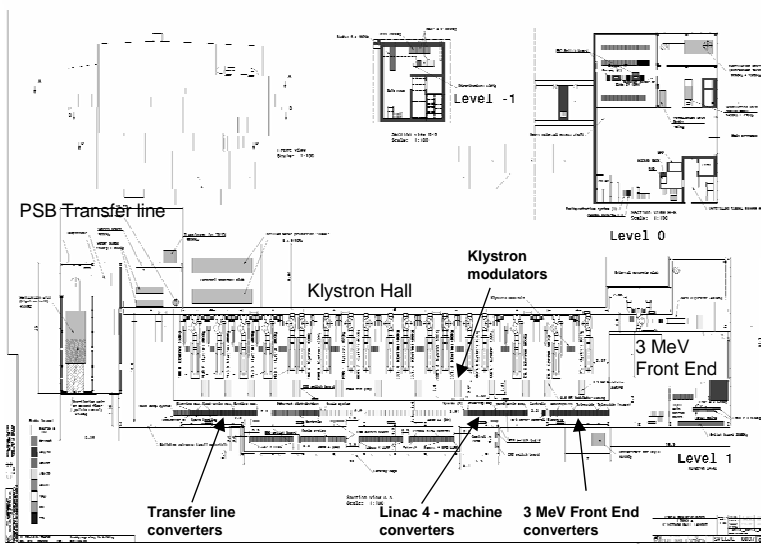


| Power Converter type   | Section(s) in the machine           | Ratings                  | Qty (*)    | Total (*) |
|------------------------|-------------------------------------|--------------------------|------------|-----------|
| HV, DC                 | H- Source                           | 60kV, 2mA, DC            | 1          | 4         |
|                        |                                     | 22kV, 300mA, DC          | 1          |           |
|                        |                                     | 2kV, 1A, DC              | 1          |           |
|                        |                                     | 500V, 200mA, DC          | 1          |           |
| LPSS                   | Chopper line steering magnets       | 35V, 20A, DC             | 1          | 1         |
| LPSSbip                | LEBT steering magnets               | 20V, 10A, DC             | 3          | 3         |
| LPS2                   | LEBT bending magnets                | 35V, 50A, DC             | 1          | 1         |
| MaxiDisCap             | Chopper line quadrupole magnets     | 1kV, 200A, 600µs / 2Hz   | 11         | 11        |
| MiniDisCap             | DTL, CCDTL, PIMS steering magnets   | 600V, 20A, 1.2 ms / 2Hz  | 30         | 40        |
|                        | Transfer line steering magnets      |                          | 10         |           |
| MaxiDisCap             | DTL, CCDTL, PIMS quadrupole magnets | 1 kV, 200A, 1.2ms / 2 Hz | 23         | 40        |
|                        | Transfer line quadrupole magnets    |                          | 17         |           |
| HardSwitching          | DTL, CCDTL, PIMS bending magnets    | 250V, 1000A, funct / 2Hz | 2          | 2         |
| HighCurrentDisCap      | Booster Injection Septa magnets     | 300V, 20kA, 600µs / 2Hz  | 3          | 3         |
| <b>Grand Total (*)</b> |                                     |                          | <b>105</b> |           |

(\*) - Spares not included

| Klystron modulators | Section(s) in the machine | Ratings                 | Qty (*) | Total (*) |
|---------------------|---------------------------|-------------------------|---------|-----------|
| Klystron Modulators | RFQ, DTL, CCDTL, PIMS     | 120kV, 40A, 1.2ms / 2Hz | 14      | 14        |

(\*) - Spares not included



- A significant work has been carried out in the last decade at CERN, to develop pulsed power converters for magnets (quadrupoles, steerers, septa, bendings), however **pulse flat-tops were always below  $\sim 600 \mu\text{s}$** ;
- The klystron modulator prototype (3 MeV Front End RFQ) **is also limited to  $600 \mu\text{s}$  flat-top**, and the peak power is  $< 50\%$  of the Linac 4 ones.
- The 3 MeV Test Stand power converters will be re-used for the Linac 4 machine 3 MeV Front End, **however operation is limited to  $600 \mu\text{s}$  flat-top**;
- **The passage from the  $600 \mu\text{s}$  to 1.2ms flat-top is a main issue** and requires re-engineering and new prototyping for a majority of systems;
- Engineering review for the steering and quadrupole power converters needed:
  1. Integration of the new FGC3 remote controller;
  2. New dimensioning of components for operation at larger pulses (1.2 ms flat-top);
- Call for tendering and contracting follow-up for industrial series production to be launched;
- The great challenges will be:
  1. Development of the new 20kA power converters for Booster Injection Septa;
  2. Development of the long pulse klystron modulators (120kV, 40A, 1.2ms flat-top / 2Hz);