HL-LHC power converter requirements
Thermal settling drift

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HL-LHC Power converter requirements

- Requirements were revised and approved this year, new version of CERN-ACC-2017-0101 document to be released
- As a reminder, values and definitions of some parameters were revised, and the effect of temperature considered separetely, as shown below

	PC REQUIREMENTS SUMMARY - ACCURACY CLASSES				
	0	**1**	**2**	**3**	**4**
Resolution [ppm]	0.5	0.5	1.0	1.0	1.0
Initial uncertainty after cal [2xrms ppm] normal	2.0	2.0	3.0	7.0	10.0
Linearity [ppm] [max abs ppm] uniform	2.0	2.0	5.0	8.0	9.0
Stability during a fill (12h) [max abs ppm] uniform	0.7	1.9	5.0	8.0	9.5
Short term stability (20min) [2xrms ppm] normal	0.2	0.4	1.2	2.0	5.0
Noise (<500Hz) [2xrms ppm] normal	3.0	5.0	7.0	15.0	19.0
Fill to fill repeatability [2xrms ppm] normal	0.4	0.8	2.6	4.0	5.0
Long term fill to fill stability [max abs ppm] uniform	8.0	8.0	19.0	40.0	45.0
Temperature coefficient [max abs ppm/C] uniform	1.0	1.2	2.5	5.5	6.5
12h Delta T for HL-LHC [max C] constant	0.5	1.0	5.0	5.0	5.0
1 y Delta T for HL-LHC [max C] constant	0.5	1.0	5.0	5.0	5.0

	0	**1**	**2**	**3**	**4**
Stability during a fill (12h) [2xrms ppm]	1.0	2.6	15.5	33.1	39.1
Fill to fill repeatability [2xrms ppm]	0.7	1.6	14.7	32.0	37.9
long term fill to fill stability [2xrms ppm]	9.3	9.3	26.3	56.1	64.1

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- For the HL-LHC, the temperature variations are known (estimated) and the TC can be used to recalculate some of the parameters:
    - Stability during a fill (12h)
    - Fill to fill repeatability
    - Long Term stability

- For example for Long Term Stability (LTS) the new uncertainty is:

$$U = \sqrt{(\Delta T * \frac{TC}{\sqrt{3}})^2 + (\frac{LTS}{\sqrt{3}})^2}$$

- For the case of Filll to Fill Repeatibility (FFR), since this parameter is already given in 2*RMS, the calculation is as follows:

$$U = \sqrt{(\Delta T * \frac{TC}{\sqrt{3}})^2 + (\frac{FFR}{2})^2}$$

(Details in EDMS 2048827)

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- The final values are presented in 2 x RMS. resulting in the final table shown below..

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Noise (<500Hz) [2xrms ppm] normal	3.0	5.0	7.0	15.0	19.0
Fill to fill repeatability [2xrms ppm]	**0.7**	**1.6**	**14.5**	**32.0**	**38.0**
Long term fill to fill stability [2xrms ppm]	**9.5**	**9.5**	**26.5**	**56.0**	**64.0**

- The distributions and limits of the parameters impacted by the temperature variation change with respect to the previous table.

Details in EDMS doc 2048827

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- The performance of power converters described above is essentially defined by:
  - ADCs (Analogue to digital conversion), DCCTs (current measurement) and Current regulation loop -> Low Frequency
  - Voltage source and load -> Medium and high frequency

HL-LHC Power converter requirements

Therefore...

- Performance requirements for the power converter translate into even tighter performance requirements for ADCs and DCCTs.
- For example, class 0 requirement for 12h stability of a power converter is 0.7ppm and for the DCCT it is 0.5ppm.

	Class 0			
	FGC3.2-EXT-AC-D0			
	total PC	**dcct**	**adc**	**notes**
Resolution [ppm]	0.5		0.2	
Initial uncertainty after cal [2xrms ppm] normal	2.0	1.0	1.0	sum of rms
Linearity [ppm] [max abs ppm] uniform	2.0	1.0	1.0	sum of max
Stability during a fill (12h) [max abs ppm] uniform	0.7	0.5	0.2	sum of max
Short term stability (20min) [2xrms ppm] normal	0.2	0.1	0.1	sum of rms
Noise (<500Hz) [2xrms ppm] normal	3.0	2.0	1.0	sum of rms
Fill to fill repeatability [2xrms ppm] normal	0.4	0.3	0.1	sum of rms
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Temperature coefficient [max abs ppm/C] uniform	1.0	0.8	0.2	sum of max

The DCCTs

- DCCTs are power devices that measure high (e.g. 18kA) currents by transforming them down to smaller currents (e.g. 5A)
- **A current step in the power converter corresponds to a current step in the DCCT and therefore a power dissipation step**
- As a consequence, a drift due to thermal settling of the resistor used to measure the DCCT output current, is more likely to happen during ther first minutes after a current step

Impact for HL-LHC

- The LHC ramps up the current in 10..20 minutes. On arrival to flat top we expect the DCCT to have higher drift in the first few minutes.

- **Until now :** this drift was included in the 12h stability specification, but if we exclude the initial 5 minutes after arrival to the flat top, a critical specification of the DCCT could be relaxed

- It seems reasonable to assume that the machine doesn't need to operate at full performance on arrival to the flat top (no physics), so...

- **Can we consider a period of 5 minutes were the DCCTs are allowed to settle, before they have to perform within the 12h stability ?**

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- If yes, then the following new table is proposed, including a new specification:
    - ***Stability at the end of ramp (5min):*** *Variation of the delivered current (for a constant reference) during the first 5 minutes after the current reaches the flat top*

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Initial uncertainty after cal [2xrms ppm] normal	2.0	2.0	3.0	7.0	10.0
Linearity [ppm] [max abs ppm] uniform	2.0	2.0	5.0	8.0	9.0
Thermal settling drift - first 5 minutes of flat top [max abs ppm] uniform	**0.5**	**1.5**	**1.5**	**3.0**	**6.0**
Stability during a fill (12h) [2xrms ppm]	1.0	2.6	15.5	33.0	39.0
Short term stability (20min) [2xrms ppm] normal	0.2	0.4	1.2	2.0	5.0
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