Functional specifications review for the stripping foil BSW magnets power converters

- Introduction (specs, topology)
- Integration
- Connections with power converter
- Development strategy
- Activities & Priorities
- Milestones schedule
- Next actions

Davide Aguglia (TE-EPC), Nov. 13th 2014
Introduction

- 16 power converters required for individually feeding 16 magnets
- 2 types of converters (BSW1 different from BSW2, 3, & 4)
- 2 spares power converters – total of 18 converters

<table>
<thead>
<tr>
<th></th>
<th>BSW1</th>
<th>BSW2&amp;3</th>
<th>BSW4</th>
</tr>
</thead>
<tbody>
<tr>
<td>L (μH)</td>
<td>13</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>R (mΩ)</td>
<td>3.5</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>$I_{peak}$ (A)</td>
<td>6700</td>
<td>3400</td>
<td>3400</td>
</tr>
<tr>
<td>$I_{rms}$ (A)</td>
<td>463</td>
<td>231</td>
<td>231</td>
</tr>
<tr>
<td>$V_{max}$ (V)</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
</tbody>
</table>

BSW1, BSW2, BSW3, BSW4

BSW magnet’s electrical specifications
Introduction

Overall current/voltage specification

Beam injection

$t_{\text{rise}}$, $t_{\text{flat}}$, $t_{\text{fall}}$, $t_{\text{rep}}$

Because infinite $dv/dt$ not possible, current smoothing agreed with beam optics

Absolute precision:
100 ppm (±50 ppm) during flat-top (starting from when beam is injected)
1000 ppm (±500 ppm) during ramp-down

~40 kHz harmonic content – amplitude ~50 ppm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{\text{rise}}$ (ms)</td>
<td>5</td>
</tr>
<tr>
<td>$t_{\text{flat}}$ (ms)</td>
<td>1 to 2</td>
</tr>
<tr>
<td>$t_{\text{fall}}$ (ms)</td>
<td>5</td>
</tr>
<tr>
<td>$t_{\text{rep}}$ (ms)</td>
<td>900</td>
</tr>
</tbody>
</table>
Evaluated topology

Power converter topology and features

EPC-MPC new APOLO power stack under evaluation:

- H-Bridge equipped with 1.7kV-1.6kA IGBTs
- Tests undergoing to check if they can be used for this project – 95% probability!
- If yes, two APOLO modules in parallel enough
**Integration**

**Simplified analysis – cable length issue**

- If cable length increases, $L_{cs}$ increases
- $di/dt$ imposed by specs
- $V_{conv}$ and $V_{sec}$ increase as well!
- Power converter maximum power, volume, losses, and cost increase with cable length!!!
- Overall design parameters are:
  - transformer ratio $k$ and
  - cable length!

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**Simplified analysis**

\[ 800 \ V \geq (L'_{mag} + L'_{cs}) \frac{di_{conv}}{dt} \]

\[ k = \frac{i_{mag}}{i_{conv}} \]

\[ 800 \ V \geq (L_{mag} + L_{cs}) \frac{di_{mag}}{dt} k \]
Integration

Analysis – limitations vs cable length & type

2 conductors of 150mm², L=0.6\mu H/m:
4 conductors of 75mm², L=0.26\mu H/m:

Converters power, volume and cost increase with cable length (analysis considering resistive effects):

- 2 conductors cable @ 150 mm²
- 4 conductors cable @ 75 mm²
- 4 conductors cable @ 95 mm²

Current limit for existing EPC power stack re-utilization.
Possibility of deporting pulse transformers of BSW2, 3, & 4 nearer to the magnet:

Pulse transformers and current measurement systems
Reserved space in BRF2 (bld. 361) for power conv. racks

- Each converter 3 racks (fighting for 2...)
- Access from front and rear of each rack! 56 racks total
- Existing RF equipment to be moved; renovation/re-installation of RF equipment coordinated with TE-EPC to optimally re-configure the space
- Power distribution/switchgears to be renovated (RF) and extended (strip foil)
- Water cooling probably needed (taps available – should not be an issue)
- False floor to be modified/reinforced
Integration

Evaluated solution for cable length minimization from BRF2 down to magnets

• Cable path studies showed an issue in finding a suitable cable gallery with appropriate length
• The option of a new cable trench/passage from BRF2 down to the injection area (1L1) into the tunnel has been preliminarily investigated
• Very rough cost estimation was made, and a total of ~2 MCHF would be necessary to construct a new cable trench illustrated in green
• Too expensive, other solutions can be found
Integration

Most likely solution – deporting BSW2, 3, & 4 pulse transformers

Identified possible zone for BSW2, 3, & 4 pulse transformers

- Identified old access shaft to the PSB tunnel
- Verifications undergoing DGS/RP for the utilisation of this zone.
- Advantages with this solution:
  - Shortening the secondary cables lengths
  - Equalize the secondary cable length such that the converters current controls algorithms are exactly the same (simplified operation and spares organization).
  - Have a unique pulse transformer spare in the same zone and reduce PSB
  - Downtime in case of a pulse transformer or DCCT failure.
Integration

BSW1 pulse transformers

• Shall be placed next to injection region
• Either on concrete slab or false floor reinforcement
• Secondary cables or bus-bars to be selected
Half Sector Test in a nutshell

- Same power converters to be re-used in PSB (BSW2&4)
- Power converters ready in early 2016!
- 2 x power converters installed in Bldg. 400
- BSW3 & 4 magnets installed in L4-PSB transfer line
- Cable length: 70m. If shorter in PSB, pulse transformers are different
- Pulse transformers installed inside PC racks
- Water cooling and power distribution to be defined
Connections with power converters / summary

**BSW1 converters (PSB only)**
- AC distribution cables (with neutral)
- Water cooling
- BIS
- Primary DC cables
- Secondary cables/busbars
- DCCTs cabling
- Magnet interlock cable/interface

**BSW2,3,4 converters (PSB & HST)**
As above with transformer outside tunnel

Pulse transformers either inside power converter rack or in the identified zone of Fig. 10
General development strategy

Reminder:
- HST power converters (PC) ready (before commissioning) by early 2016
- PSB PC ready (before commissioning) by end 2017

Strategy:
- Same PC for BSW1 and BSW2,3, & 4 – only pulse transformer and current measuring system differ
- Re-utilization of existing power stack design—probably no MS-IT procedure!
- 3 PCs ready by early 2016 – 2 x BSW3 & 4, and 1 x BSW1. Power stacks for prototypes via recent contract options
- Reception at CERN of main series components (chargers, capacitors, power stacks, DCCTs) by end 2016
- MS-IT procedures for chargers (~200kCHF), DCCTs (~200kCHF), pulse transformers, and power converters assembly
Activities and priorities

LIU-PSB strip, foil PC

1. Design
   - capacitor bank value
   - charger specs
   - 3-Level simulation
   - Apollo stack with Gilles/Urban-Marc
   - Filter design
   - passive damping?
   - verify EMC in 3-Level control
   - switching frequency fixed
   - thermal study: water or no water?
   - platine 50Hz distrib
   - Write DCCT specification

2. Purchasing
   - Capacitor chargers
     January 2015 (done with F3)
   - Trasfor study
   - Pulse transformers
     - bias or not?
   - Integration
   - Power stack (apollo)
   - capacitor bank
   - filter inductances
   - filter capacitors
   - IT for series assembly

3. Assembling & cabling
   - Reg FGC3 or Siramatrix?
   - Current regulation in FGC3?
   - general schematic
   - final schematic for cabling
   - 3D integration
   - connectors and cables type

4. Budget
   - APT/EVM reporting
   - CET tracking

5. Project Management
   - WU description
   - Functional specification
   - Design report
   - Tests report
   - Operational note
   - Load doc in EDMS

6. Documentation
   - Apollo drivers tests
   - 3-L levles control test
   - EMC tests

7. Installation
   - BSW 234 sec. cables length
   - DCCTs cables length & path

8. Control Electronics
   - Reg FGC3 or Siramatrix?
   - Current regulation in FGC3?

9. Rack integration
   - 2 stacks in one rack?
   - reduce water space
   - reduce maines space

Legend:
- Priority 1
- Priority 2
- Priority 3
- 1/4 Done
- 1/2 Done
- 3/4 Done
- D&B
- Davide
- Nicolas

Milestones / expenditures APT/EVM

References
### Milestones Schedule

**Major milestones and activities**

<table>
<thead>
<tr>
<th>Description</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
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<tbody>
<tr>
<td>Eng. design</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
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<tr>
<td>Parts for HST + BSW1</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
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<tr>
<td>HST PC construction</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
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<tr>
<td>Series prod MS-IT</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
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<tr>
<td>Parts 4 series (MS-IT)</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
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<tr>
<td>Transfo MS-IT</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
</tr>
<tr>
<td>Series assembling</td>
<td>Sept-Dec</td>
<td>Jan–Apr</td>
<td>May-Aug</td>
<td>Sept-Dec</td>
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</tbody>
</table>

Installation and commissioning in 2018
## Actions for finalizing functional spec.

Major actions to finalize functional spec. and finalize design / start purchasing

<table>
<thead>
<tr>
<th>Item #</th>
<th>Objective</th>
<th>who</th>
<th>By date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Confirm that 50 ppm 40 kHz current ripple acceptable</td>
<td>TE/ABT</td>
<td>Now</td>
</tr>
<tr>
<td>2</td>
<td>Cable length between pulse transformers and magnet</td>
<td>EN/EL</td>
<td>21st Nov.</td>
</tr>
<tr>
<td>3</td>
<td>Cable distance and path for BSW1 DCCTs (current measurement)</td>
<td>EN/EL</td>
<td>21st Nov.</td>
</tr>
<tr>
<td>4</td>
<td>Dimensions of identified zone for pulse transformers</td>
<td>EN/EL – EN/MEF</td>
<td>28th Nov.</td>
</tr>
<tr>
<td>5</td>
<td>Define the interfaces, type and number of cables, for magnet interlock. Actions with</td>
<td>TE/EPC - TE/ABT</td>
<td>5th Dec.</td>
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<tr>
<td>6</td>
<td>Define timing management solutions.</td>
<td>TE/EPC – BE/OP</td>
<td>12th Dec.</td>
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<tr>
<td>7</td>
<td>Define BIS current tolerance for safe operation in the PSB and HST.</td>
<td>BE/ABP – BE/OP</td>
<td>12th Dec.</td>
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<tr>
<td>8</td>
<td>BRF2 global integration studies considering RF renovation + HST global integration study</td>
<td>TE/EPC - BE/RF EN/MEF – EN/EL</td>
<td>Early 2015</td>
</tr>
<tr>
<td>9</td>
<td>Water distribution needs and work</td>
<td>TE/EPC – EN/CV</td>
<td>Early 2015</td>
</tr>
</tbody>
</table>