SPS energy saving system for greater availability and reliability

Abstract
The Super Proton Synchrotron is the main injector for the Large Hadron Collider (LHC). The 7 km SPS accelerates particles from 14 to 450 GeV. The deployment of the new Function Generator Controller allowed the development of an energy saving system optimising the magnetic cycle by pulsing only when needed. The FGC framework in the SPS will simplify operation and add more flexibility, reliability and availability. This system will be the new standard across the accelerator complex.

CERN’s Accelerator Complex

**Table: SPS Users**

<table>
<thead>
<tr>
<th>SPS Users</th>
<th>Injection energy</th>
<th>Flat top energy</th>
<th>Extraction type</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Area</td>
<td>14 GeV</td>
<td>60 to 450 GeV</td>
<td>Slow extraction</td>
</tr>
<tr>
<td>LHC (Pilot, 25ns)</td>
<td>25 GeV</td>
<td>450 GeV</td>
<td>Fast extraction</td>
</tr>
<tr>
<td>CNGS (Cern Neutrons)</td>
<td>14 to 26 GeV</td>
<td>400 GeV</td>
<td>Fast extraction</td>
</tr>
<tr>
<td>Hiradmat</td>
<td>26 GeV</td>
<td>440 GeV</td>
<td>Fast extraction</td>
</tr>
<tr>
<td>MD pulsed</td>
<td>14 to 26 GeV</td>
<td>80 to 450 GeV</td>
<td>No extraction</td>
</tr>
<tr>
<td>MD coastable</td>
<td>26 GeV</td>
<td>26 to 270 GeV</td>
<td>No extraction</td>
</tr>
<tr>
<td>North Area (Pilot)</td>
<td>17.07 GeV</td>
<td>27 to 450 GeV</td>
<td>Slow extraction</td>
</tr>
<tr>
<td>LHC (Pilot, 200ns)</td>
<td>17.07 GeV</td>
<td>450 GeV</td>
<td>Fast extraction</td>
</tr>
<tr>
<td>MD Pulsed</td>
<td>17.07 GeV</td>
<td>80 to 450 GeV</td>
<td>No extraction</td>
</tr>
<tr>
<td>MD coastable</td>
<td>17.07 GeV</td>
<td>17.07 to 270 GeV</td>
<td>No extraction</td>
</tr>
</tbody>
</table>

**SPS Dynamic Economy**
Triggred automatically by the level of the beam intensity.
- Main Dipole Power Supplies stay at injection energy
- All ring circuits stay at minimum current
- All transfer line circuits except injection line (TT10) stay at minimum current because the next beam injection on the same cycle passes through TT10 to go to the injection dump.
- The scraper will not execute its cycle.
- We can force the pulse manually for verification purposes.

**Fast Beam Detection**
a) BCT3, BCT4 (Beam current transformer) will:
- Publish intensity in the ring at 20 ms after injection.
b) BCTECO (Economy server) will:
- Subscribe and compare the value with a threshold for each cycle.
- If Value < threshold:
  - Open the loop of the Beam Interlock Controller (firing emergency dump).
  - Triggers the LOCAL TIMING which in turn triggers the economy event generation in the cable.
  - Closed the loop of the Beam Interlock Controller at the end of the cycle.
c) On this timing event:
- The emergency dump is fired a second time for redundancy.
- All FGC states switch to partial economy.
All of this must be executed in ~40 ms.

**SPS Full Economy**
Triggred by manual switch of external condition or a missing signal from electricity network supplier.
- Timing system will publish an event Full Eco in telegram.
- Main Dipole Power Supplies stay at 13.5 GeV for all cycles.
- All ring circuits stay at 13.5 GeV.
- All transfer line circuits including TT10 stay at minimum current.
- 660 circuits switch on full economy.
- We can force the pulse manually for verification purposes.

**Full Economy Control**

**Transfer Line Dynamic Destination Economy**

**Dynamic Destination Economy Triggered**

With these three modes of economy not only do we gain an electrical energy saving but also we solicit the transformers, the power converters, the magnets and the vacuum chambers inside the dipoles only when beam is present in the machine.

We therefore increase the life span of each element of the machine and in turn the reliability and availability of the SPS complex as a whole.