Investigation on a high power solid-state pulse generator

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Introduction

• Solid-state PPS characterized by high repeatability, high reliability, long lifetime, free maintenance and easy-to-use
• Such systems with moderate peak power (sub GW) are widely applied in high average power region
• Pursuing higher peak power with quasi square waveform for HPM, X-ray and more industrial applications...

S-3N 400kV 16kW (Burst)  OSU 60 kV/75kW bipolar pulser  10GW/160 ns/20 Hz
Introduction

• **Switch**
  - high power capability
  - large power compression ratio
  - high switch speed
  - low switch impedance
  - high repetition rate and long lifetime

• **Insulation**
  - components still restricted to relatively low rated voltage
  - finish the power compression under lower voltage
  - fully profit the insulation rules

• **Energy transfer efficiency**
  - reducing energy lost is essential
  - important for thermal management

* magnetic switch
* low impedance pulse forming
* close-loop pulse transformer
System design

- High power magnetic switch based pulse modulation
- Low impedance pulse forming network
- Induction voltage adder for voltage step-up
- Modularization

A High Power, Low Impedance and Long Pulse Generator

Voltage Adder

Investigation on a High Power, Low Impedance, and Long Pulse Generator Based on Magnetic Switches

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Circuit simulation

Circuit model

- Three magnetic switches for pulse modulation
- IVA performs dual functions of charging inductor and adder

![Schematic of a high power solid-state pulse generator](image)

![Schematic of a high power, low impedance and long pulse generator](image)
Circuit simulation

Simulation results

- IVA completes the dual functions well

<table>
<thead>
<tr>
<th>$T_{FC}$</th>
<th>$Z_{FC}$</th>
<th>$L_C$</th>
<th>$L_{m,IVA}$</th>
<th>$L_{s,IVA}$</th>
<th>$R_{load}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20ns</td>
<td>12Ω</td>
<td>29nH</td>
<td>18μH</td>
<td>100nH</td>
<td>50Ω</td>
</tr>
</tbody>
</table>

PFN charging and discharging voltage

Output pulse voltage on the load
Electromagnetic simulation

IVA response characteristics

- Symmetrical feeding responses much faster
- IVA with fewer stages performs better

<table>
<thead>
<tr>
<th>core material</th>
<th>outer diameter</th>
<th>inner diameter</th>
<th>height</th>
<th>thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>2605SA-1</td>
<td>406 mm</td>
<td>274 mm</td>
<td>20 mm</td>
<td>25 μm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>width</th>
<th>$B_s$</th>
<th>$B_r$</th>
<th>Insulation</th>
<th>stacking factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mm</td>
<td>~1.56 T</td>
<td>≥1.4 T</td>
<td>120 V/layer</td>
<td>~0.82</td>
</tr>
</tbody>
</table>

Symmetrical feeding structure of the cell

Four-stage IVA

Simulation results of the IVA
Experimental test

Key sub-systems

- HVPS: AC-link, 0-30 kV/60 kJ/s
- Transformer: 0-150 kV/15μH
- MPC: 2-stage/20:1, Fe-based amorphous

HVPS

Close-loop pulse transformer

Magnetic pulse compressor

BH curve measurement
Experimental test

Key sub-systems

- Magnetic switch: coaxial winding and output ports
- Low impedance PFN: symmetrically circumferential structure
- IVA: symmetrical fed modules with $v \cdot s$ product of 24mV·s
Experimental test

Ceramic capacitor test

- Rep. test in μs region
- 40nF/80kV/10Hz/60s
- Further analysis of failure mechanism

Test platform:
- Magnetic switch
- PSS1
- Primary Capacitor
- HVPS input
- Transformer
- Trigger unit
- Reset circuit
- Test cell with PFN, PSS2 and water resistor

Test cavity
- PFN
- Water resistor
- Test waveforms

Normal status vs Capacitor broken

Test waveforms

Broken capacitors
Experimental test

Primary test results

- On-line DC reset condition
- 2.1GW/170ns/20Hz
- Risetime~50ns
- Prepulse~10%
- Energy transfer ratio~45%

Overlap mode

Sequential mode
Experimental test

Upgraded test results

• Magnetic switches and PFN upgraded
• 5.5GW/170ns/20Hz/5s
• Showing good repeatability and stability

Upgrade system

Overlap of 100 pulses
Conclusions

- A scheme for GW-level solid-state generator is put forward based on magnetic switch, low impedance PFN and IVA
- The latest results are 5.5GW/170ns/20Hz/5s, showing good repeatability and stability
- The primary switch would be replaced with semiconductor for all solid-state system

**SMART: Solid-state Magnetic switched Accelerator for Repetitive Test**
Thanks for your attention!