Klystron Modulator 2-Pack

NLC Collaboration Meeting
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Why Revisit 2-Pack?

• Baseline Change from DLDS to SLED II Model changes ground rules
  – 8-Pack was optimized for DLDS that required linear summing of power from 8 – 75 MW klystrons.
  – Adoption of SLED II RF distribution makes each pair of klystrons functionally independent from any other pair.
    • Each pair powers a 6.5 m section of linac w/ 400 nsec 500 MW pulses.
    • The “natural RF power building block is now a 2-Pack vs. an 8-Pack.
    • Physically 2-Packs can be placed in close proximity or not, depending on optimization of overall requirements for penetrations, RF and BPM cabling and other tunnel electronics.

• Optimization of SLED II NLC for 2-Packs should be studied.
Recent Modulator Developments

- New DFM Prototype Under Design & Construction in FY03
  - 6.5 kV IGBTs operating @ 4 kV vs. present 2.2 kV/Cell
  - Fewer cells & driver boards required for final unit.
  - Will build 2 “10-stacks” in FY03 under present plan.
  - Full 8-Pack unit now planned for FY04.
  - Cells designed for 3.2 usec operation (SLED II reduced to 1.6usec).
  - Investigating option of modular power supply on each driver board.
  - Essentially makes each driver an independently powered subsystem.
  - Controls being redesigned with conversion, communications intelligence on each driver board.
  - Each modulator will have a PLC interface to main interlock & control system.
Induction 2- Pack Not New!

• Originally studied for Injection Linacs where SLEDed 2-Packs were used
  – Short stack of cells transformer-matched to klystron pairs.
  – Fractional turn primary as in 8-Pack, w/ multi-turn secondary.
  – For X-Band:
    • Load = 2 - 75 MW klystrons, 500 kV, 520A peak for pair
    • Single driver board delivers 3000A at 4 kV.
    • Two boards driving each Metglas cell give 6000A at 4 kV.
    • Transformer turns ratio $N_1$ and No. Cells $N_2$ given by:
      $N_1 = \frac{I_{\text{stack}}}{I_{\text{load}}} = \frac{6000}{520} = 11.5 \Rightarrow 11$ (~5% current margin)
      $4kV \times N_1 \times N_2 = 500kV$ where $N_2 = \text{No. Cells}$
      $N_2 = \frac{500}{(4 \times 11)} = 11.3 \Rightarrow 12$ cells (~5% voltage margin)
    • Use 12 cells with 11 turns for optimum match.
    • Could add more cells for redundancy to improve unit MTBF.
2-Pack Construction

• Modeled in 1999 by R. Cassel for Injection Linacs
• Use Metglas cores but with elongated shape to enable multiple turn HV secondary “basket” construction.
• Package for modularity and ease of access, replacement of modules.
• Main modules are:
  – Klystrons (2)
  – Driver card stacks (2)*
  – Pulse transformer and tank (1 with two coupled Metglas stacks)
  – * Contain driver cards with on-board HVPS, Controls & Interlock protection
2-Pack Package Example – R. Cassel

500 kv 500A @ 15uSec
12 ea cores @ 0.024 V-Sec/turn per core
0.144 V-Sec/turn total
8.4 kV/turn @ 15uSec
2 series core 1 turn, 60 turn secondary
2 each 4.2kV, in series IGBT drivers
~700 uhy, 1000 ohms t=0.7 usec rise time
2-Pack Cost Considerations

• Cost of a 2-Pack ~ 8-Pack/4
  – Metglas and IGBTs main cost drivers.
  – Labor cost << materials.
  – Slight increase in metal housings and controls more than offset by increased benefits of higher volume (learning curves).
  – Slight increase footprint needed to optimize access to modules.
  – Easier to move, assemble and service than 8-Pack.
2-Pack Advantages in SLED II System

- Assume parallel tunnels & full access for servicing.
- Improved Machine Availability
  - Failure of a 2-Pack brings down 2 rather than 8 klystrons.
  - Less energy drop in beam by 4x for each failure.
  - In Maintainability model, failed units can be repaired in parallel.
  - Aggregate MTTR reduced & Machine Availability improved.
- *Lower Risk to klystrons in case of Arcs.*
  - 8-Pack can produce 4X the joules into an arc than a 2-Pack. Long term effects unknown but not likely to be beneficial.
- Improved Modularity for Installation and Servicing
  - Possible to pre-assemble, transport and install as a unit – impossible with 8-Pack.
- Linear spacing of 2-Packs in tunnel can optimize waveguide lengths to loads.
- 2-Packs can be independently timed for better matching to SLED & power delivery system delays.
2-Pack Advantages in NLCTA 8-Pack

• 2-Pack can be utilized to provide full power testing of first pair of XP klystrons in Power Conversion lab without interference with ongoing 8-Pack testing in NLCTA.

• 2-Packs could be installed alongside of existing 8-Pack to provide additional RF power without interference to ongoing program.

• Decision can be made to cluster 2-Packs in groups of 2, 4 or 8 klystrons, or optimize using more novel schemes.
Potential Advantages to Other Systems

- Linear spacing and smaller cross section potentially reduces tunnel cross section, cost.
- Penetrations at equal 2-Pack spacing minimize cable lengths for LLRF phase pickups, cavity BPMs, and other instrumentation which can now reside in parallel tunnel.
- Need for radiation protection for sensitive Front End Electronics in main tunnel (holes in walls of inner tunnel, difficult packaging, poor access for repair) would be eliminated.
- Front End Electronics would be wall mounted, water cooled and easily accessible in parallel tunnel.
Proposed Plan for FY03-04

- Build DFM 12-stack in Power Conversion lab for testing on old 4-Dog stand.
- Use existing transformer designed for NLC conventional PFN 2-Pack to drive water load, 5045.
- Perform usual tests of stack ~ spark-down, max V,I tests.
- In parallel, design & construct new 12-stack Transformer, 1:11 ratio (or less for additional I margin) matched to 2-XP klystron loads.
- Design modular packaging system for transformer, tank & driver boards.
- Build complete prototype.
- Test with water loads, 5045s, XPs when available.
Conclusions

• 2-Pack of renewed interest for SLED II Main Linac new Baseline.
• 2-Pack remains model for all injection linacs. Core & Xfmr turns vary but driver boards could remain identical for all.
• 2-Packs pose less risk to Klystrons during Arcs than 8-Pack.
• 2-Pack costs no higher than present 8-Pack model.
• 2-Pack optimizes RF delivery in tunnel better than 8-Pack.
• 2-Packs can be clustered if more concentrated RF is needed (e.g. DLDS).
• 2-Packs distributed linearly provide better access for installation, servicing, as well as cable plant routing, placement & service of Front End Electronics such as LLRF, BPMs, Vacuum, Movers etc.
• 2-Pack can be utilized to provide full power testing of first pair of XP klystrons in Power Conversion lab without interference with ongoing 8-Pack testing in NLCTA.