NLC - The Next Linear Collider Project

NLC Solid State Induction Modulator  4-Pack Global System Design Review
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Induction Modulator Program

- Four Main Programs:
  - 1. *4-Dog*: Full power prototype driving four 5045s.
  - 3. Move Prototype to NLCTA to drive three 75XP3 with new Tank design.
  - 4. *DFM 8-Packs*: Design/build a DFM prototype Using 6.5kv IGBTs, By mid FY 2003, for NLCTA. Drive 8 – 75XP3 klystrons as available.
SOLID STATE INDUCTION MODULATOR
PROTOTYPE MODULATOR “4 DOG”

• DESIGN OF 4 DOG PROTOTYPE INDUCTION MODULATOR

• CORES AND SECONDARY
  • 76 Primaries @ 5400 A
  • 3 Turn Secondary
  • 380 kV @ 1680 A, 650 Meg watts for 3.2μs, 300 kW Ave.

• SOLID STATE DRIVERS
  – 162 IGBT’s Drivers (two per Primary)
  – 1800 volts per IGBT 3300V 800A
  – 2700 Amps per Driver
NLC Solid State Induction
Simplified Schematic

"4 Dog" Induction Modulator Test
500 kV Max
2080 A Max

4 ea 5045 KLYSTRON
400 kV 1800 A 3 µSec
725 MW pulse
350 kW Ave @ 120 Hz
Efficiency > 80%
MODULATOR CORE & CASE AND
Insulated Gate Bipolar Transistor IGBT

- 6.5” ID double ended drive core
- 0.007 Volt-Sec core
- 2.2kV 3 μS 0.5 Joules loss

**EUPEC 3300V 800 A**
**FAILURE RATE <50 FIT (x10⁻⁹ hr**
IGBT Drivers and Core

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R. Cassel
1/5/02
Slide 6
Prototype Solid State Induction Modulator
(4-Dog)

- Core Stack with drivers

Prototype Diver monitors
Modulator ONLY

Single turn secondary
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Prototype Solid State Induction Modulator

- Coaxial Three Turn Secondary End Connection
Prototype “4 Dog” Solid State Induction Modulator

3 turn Secondary with water load

With oil tank installed
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NLC Solid State Induction
500kW power supply

Output transformer rectifier  Buck regulator and switcher

Power line input
Prototype Induction Modulator Pulse
Water Load

Three Turn Secondary
76 Metglas cores
152 IGBT Drivers

250 nsec
500 kV
650 Amps
2.5 usec

100 kVOL
500 nSEC
Oct 26, 2001
Prototype Induction Modulator Pulse
2 each 5045 Klystrons

400 Kv, 900 Amps 3 usec
Three Turn Secondary
76 Metglas cores
152 IGBT Drivers
Ratio $V_{out}/V_{in} = 228$
1850 Volts DC
Prototype Induction Modulator Pulse
Water Load

Three Turn Secondary
Turn On Delayed in 20 cells

Water Load ~2k ohms with and without delayed cells

Current no cell delay

20 A/div

Current with cell delay

140 Amps

Voltage no cell delay

20 kV/div

Voltage with cell delay

260 kV
Compare Induction Modulator Pulse with PFN 5045 Klystrons Pulse Voltage

1) SLAC PFN Voltage: 50 kV, 1 usec
2) Induction Modulator Voltage: 50 kV, 1 usec

350 kV, 3.0 usec
375 Amps PFN
750 amps Induction Modulator waveform
efficiency ~89%
Overall efficiency >80%
NLC SOLID STATE INDUCTION MODULATOR PROBLEMS

- Diode Problem Turn on voltage, Qrr and snap off. (Needs R&D)
- IGBT shut off under short circuit
- Three Turn Arc transmission line problem
NLC Solid State Induction Diode Test

- TURN OFF DURING PUSE
IGBT Short Circuit Test

EUPEC 3.3 kV FZ800R33KF2

WESTCODE “Hockey Puck” IGBT
NLC Solid State Induction
76 stack Arc test

Single turn test

Three turn tests
NLC SOLID STATE INDUCTION MODULATOR
FOR 8-PACK 75XP3 KLYSTRON

• **Provide Drive Pulse for 75KP3 Klystron**
  – 8 each 75XP3 Klystrons
    • 500 kV @ 2080 A 3.2 uS
    • 120 PPS Average power 500kW

• **Provide heater, focus coils Power supply, temperature monitoring and protection of Klystrons**
  – 20V 25Amps for heater
  – 3 focus coils 10V 20A
  – Body & Collector Temperature monitoring and interlocking
  – Vacuum interlocking
NLC SOLID STATE INDUCTION MODULATOR
NEW DFM 8 PACK DESIGN

- FRACTIONAL TURN PULSE TRANSFORMER
  - MULTIPLE PRIMARIES ONE END GROUNDED
    - 46 Primaries @ 6300 A with 3 turn Secondary
    - Primary uses low losses Metglas cores
  - SECONDARY CONNECTED IN SERIES
    - 500 kV @ 2080 A, 1040 Meg watts for 3.2 μs, 500 kW Ave.

- SOLID STATE IGBT DRIVER
  - IGBT ARE BIPOLAR TRANSISTOR WITH FET INPUT GATE
  - 92 IGBT’s (two per Primary)
  - 3200 Amps for 3.2 μs each IGBT
  - 4000 volts per IGBT 6.5kV-600 A
NLC Solid State Induction Modulator
8-Pack DFM Tests at NLCTA
SOLID STATE INDUCTION MOULATOR
4-PACK TEST

Use the Prototype 4 Dog to Drive the 4 Pack Test

- **CORES AND SECONDARY**
  - 76 Primaries @ 2400 A
  - 3 Turn Secondary
  - 500 kV @ 750 A, 390 Meg watts, 100 kW Ave.

- **SOLID STATE DRIVERS**
  - 162 IGBT’s Drivers (one per Primary)
  - 2200 volts per IGBT
  - 2400 Amps per Driver
SOLID STATE INDUCTION MODULATOR FOR 4-PACK 75XP3 KLYSTRON USING “4-DOG”

- Provide Drive Pulse for 75KP3 Klystron
  - 3 each 75XP3 Klystrons
    - 500 kV @ 750 A 2.4 μS
    - Up to 1.2 Volts-Seconds FLAT TOP Maximum
    - 60 PPS Average power 100kW

- Provide Heater, focus coils current, & Temperature monitoring and protection of Klystrons
  - 20V 25Amps for heater
  - 3 focus coils 10V 20A
  - Body & Collector Temperature monitoring and interlocking
  - Vacuum interlocking
NLC 4-PACK MODULATOR

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4 PACK Induction Modulator Control System Specifications

• Provide Personal Safety protection from the modulator and klystrons.
• Provide a local and remote method of turning on and off the Induction Modulator Power Supply and Pulse.
• Provide local and remote monitoring of Induction Modulator, Klystrons, TWTs
• Provide equipment protection for the Modulator and Klystrons
• Provide turn on and shut down sequencing for the equipment.
3-Pack Induction Modulator PLC Controls

Touch Panel

SLC-500

Ladder diagram Logic
5.3 REMOTE PROGRAMMING VIA RS232

5.3.1 Introduction

The RS232 interface is accessible through the rear panel IN/OUT jacks. The jacks are 8 contacts each and conform to EIA/TIA-568A requirements. The IN and OUT jacks are used to connect the units in a RS232 or RS485 chain to a controller. The data format is ASCII, 8 bits/character no parity bit, one stop bit. The baud rate can be selected to one of the 6 possible rates between 300 and 9600bps (refer to par. 5.2.3). Refer to par. 5.8 for detailed explanation.

Up to 31 ZUP units can be connected to the RS232 control as shown in Fig. 5-1.

4.4.15 Output Good Signal

Output Good Signal is an open collector output, referenced to COM potential, indicating the status of the power supply output. While the power supply operates normally, the Output Good is low (0-0.8V). When the power supply output is disabled due to activated OVP, OTP or FOLD protection, or by OUT set to off, or by ac ON/OFF set to off, then the output signal stops conducting. The maximum sink current is 10mA and the maximum voltage is 40VDC.
NLC SOLID STATE INDUCTION MODULATOR PROGRAM

- Full modulator core stacks of 76 cores with three turn secondary to drive water load to 500 kV. **Complete**
- Then full load current at 400 kV into 2 each 5045 klystrons. **Complete**
- Arc down testing to full Voltage. **In progress.**
- Then full load current at 400 kV into 4 each 5045 klystrons. Full reputation rate **Pending Arc Tests**
- Model program using 11 cores with standard pulse transformer to drive 5045 klystrons for life time testing. **Operational, Under Test**
- Drive 3 each 75XP klystrons at full Load with new stand. **Stand under Design**
- Fabricate a second modulator to operate 8 each 75XP klystron at 500 kV full load. **Design, & Procurement Stage**
• There are several interfaces with other system.
  – 75XP3 Klystron specifications including Pulse perimeters, heater, and focus coils. Most interface complete (**Not signed off**)
  – Vacuum System Interface (**Signed off**)
    • Modulator dose all the work of wiring
  – Control system & LLRF (**Not Seen**)
  – Conventional Facilities Specification proved interface (**Not Seen**)
    • Details of water and power not specified
  – Cable plant and tray (**Not Seen**)
    • Detail yet to be specified
Missing Information

- There are several bits of missing information
  - 1) Final Mechanical layout of 75XP3 Klystron mounting bolt circle etc.
  - 2) TWT interface to klystron and its effect on modulator mechanical layout
  - 3) Layout of water piping and its interface with modulator mechanical layout
  - 4) Layout klystron shelling lead, LLRF boxes, vacuum pump boxes, tray layouts interface with modulator mechanical layout.
  - 5) Interface with Main controls, trigger, PPS, Fire, and safety interlocks
  - 6) Supports for RF distribution/ supports and its interface with modulator mechanical layout