
Optimized Converter-Modulator Design for ILC Application*

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Los Alamos High Frequency “Polyphase Resonant Power Conditioning” Compared To Conventional 60Hz Technology Is Significantly Smaller

SNS 10 Megawatt Pulse, 20 KHz, 140 kV Polyphase Resonant Converter-Modulator



- Developed for Oak Ridge SNS Accelerator
- Can be Optimized for 30 MW Long Pulse
- Operates 2 Multi-Beam Klystrons
- Resonant Conversion is Fault Tolerant
- Can Operate with Kilometer Cable Lengths
- No Crowbars Needed

Los Alamos Low Voltage Energy Storage Compared To Conventional High Voltage Method Is Very Compact And Reliable

Self-Clearing Metallized Hazy Polypropylene



- 300,000 hour lifetime
- Graceful degradation
- High frequency design, variable rep-rate capabilities
- Extremely high volumetric efficiency
- High safety factor

Conventional High Voltage Paper and Foil Capacitors



- Limited lifetime
- Explosive failure modes
- Highly frequency dependant and lossy
- Large footprint
- Poor safety factors and dangerous
- Crow Bar required

Nanocrystalline High Frequency Transformers Are Over 150 Times Lighter And Significantly Smaller

Typical H.V. Transformer



- 100 kV, 60 Hz
- 20 Amp RMS
- 2 MW Average
- 35 Tons
- ~30 KW Loss

HVCM Transformer



- 140 kV, 20 KHz
- 20 Amp RMS
- 1 MW Average (3) present use
- 450 LBS for 3
- 3 KW Loss At 2 MW

Load Protection Networks Not Needed For Los Alamos Technology

Typical H.V. Crowbar Protect Network



- Large
- Reliability concerns
- Maintenance concerns

Resonant Converter Protect Network

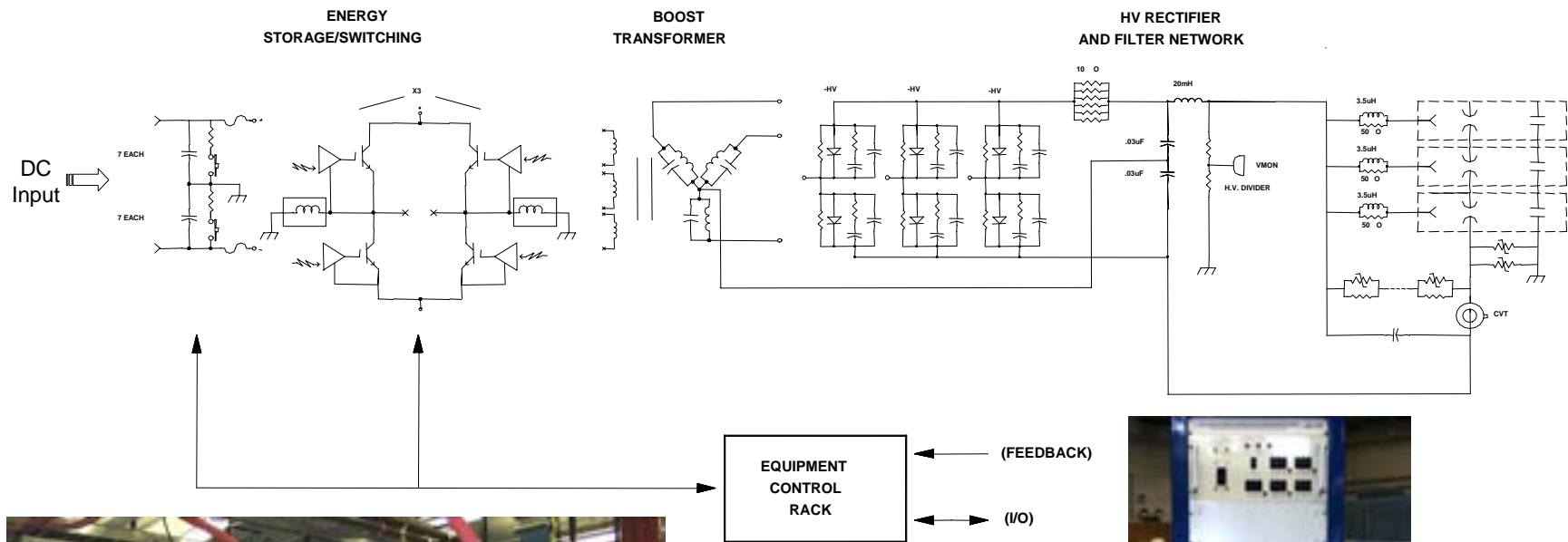
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- Converter-Modulator inherently self protective
- Automatic fault “ride-through”
- Safe for all components

Polyphase Resonant Power Conditioning Uses New LANL/LANL Funded Technology Developments

- **Low Inductance Self-Clearing Capacitors**
 - Thomson Passive Components (AVX), France
- **Low Inductance High Power Capacitors**
 - General Atomics Energy Products, San Diego, Ca.
- **Nanocrystalline Core Manufacturing**
 - MK Magnetics (Stangenes), Adelanto, Ca.
 - Uses Hitachi FT-3 Alloy
- **New Engineering Techniques**
 - Polyphase Resonant Voltage Multiplication
 - Resonant Rectification
 - Self DeQing (No crowbars and self protective)
 - Snubberless IGBT Switching

Simplified Block Diagram Of Polyphase Resonant 10 MW Pulse Converter Modulator



**High Voltage
Converter Modulator**



**Equipment
Control Rack**

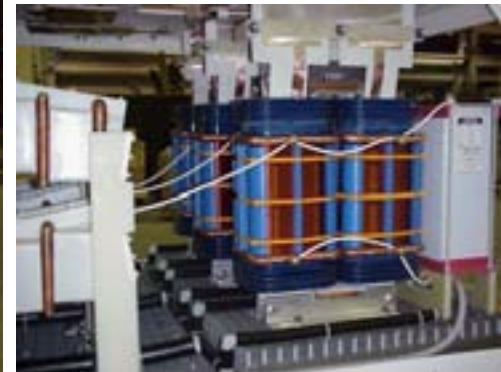
Tank Basket Assembly; 1 MW Average, 10 MW Long Pulse



Filter Network



Tank Basket Assembly



Transformers



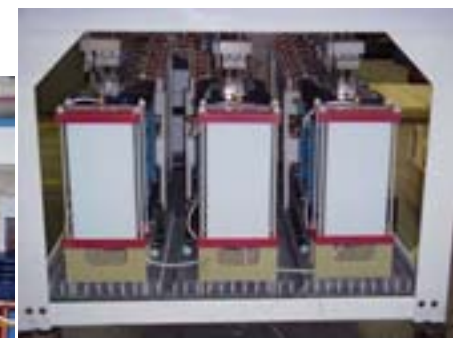
Output Sockets
&
Varistor Assembly



Oil Pump & Voltage Divider

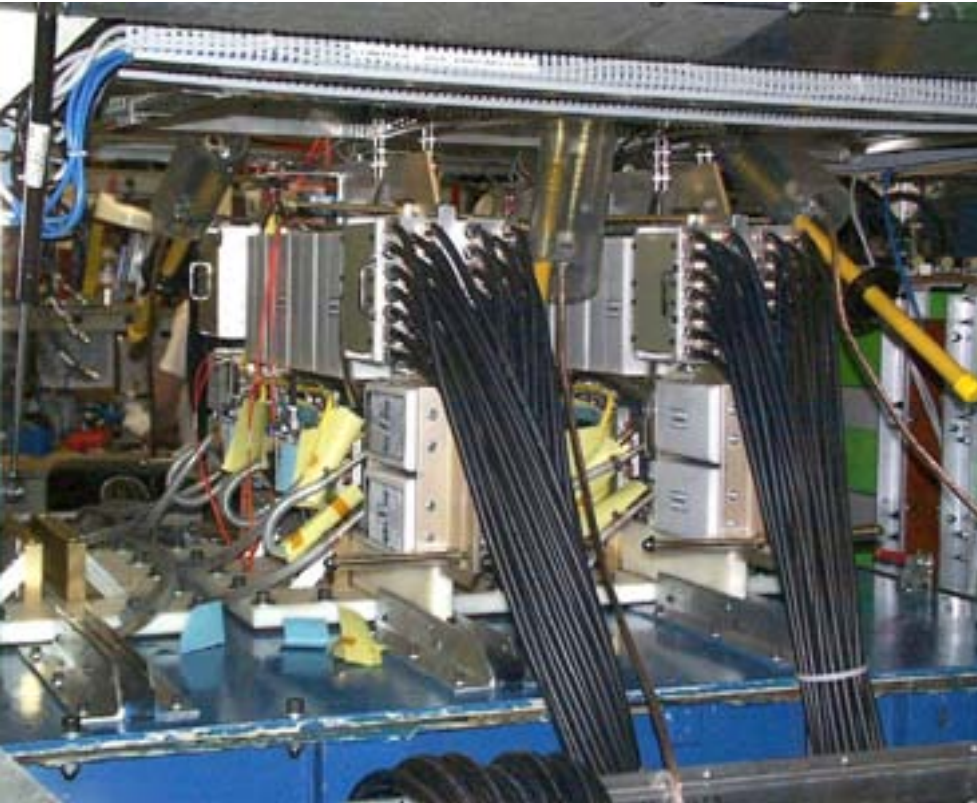


Diode Rectifiers



Transformer Resonating
Capacitors

IGBT Switch Plate Assembly; 1 MW Average, 10 MW Long Pulse



- Already operates at 10 MW switching level

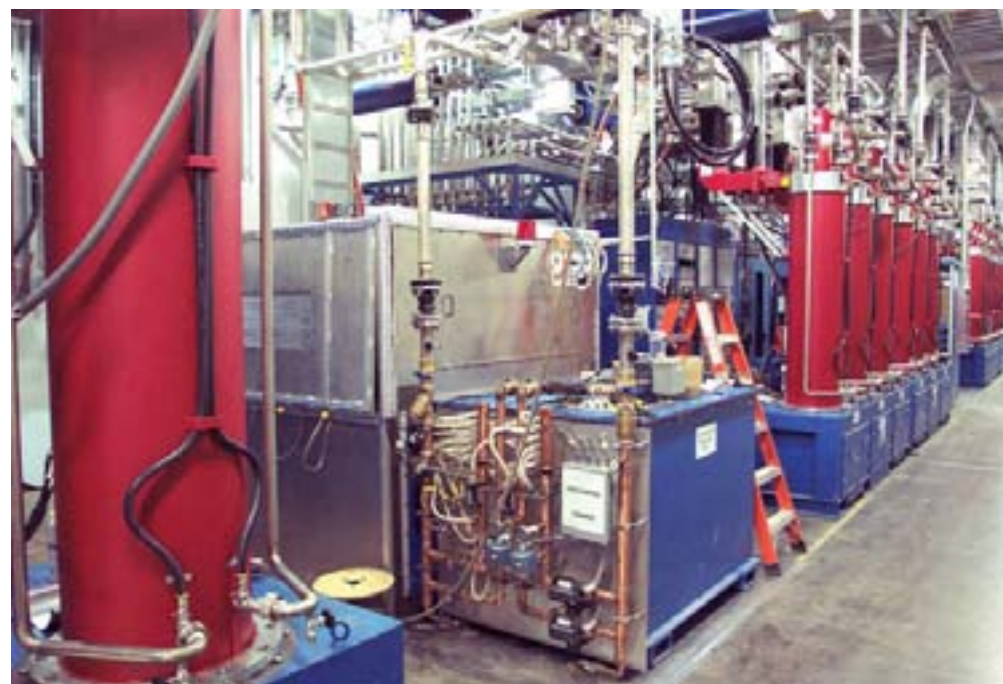
All HVCM Units Installed And Operational



CCL-ME1 with Klystron



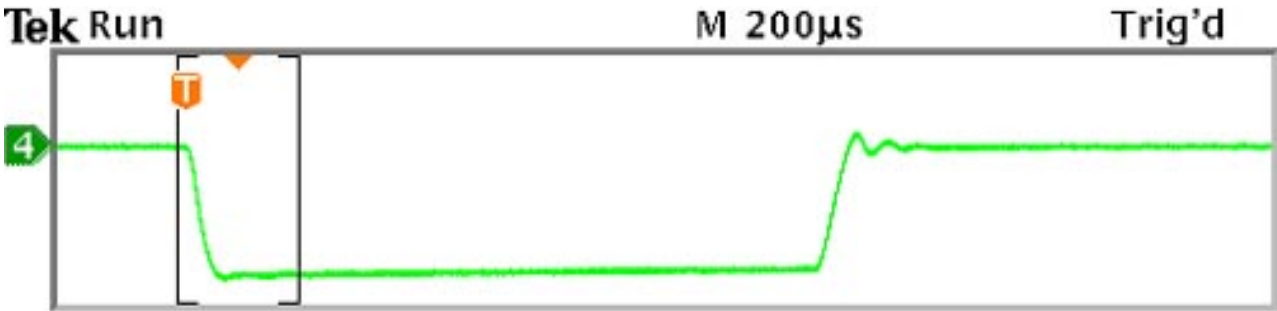
**DTL-ME3
with Klystrons
“The Workhorse”**



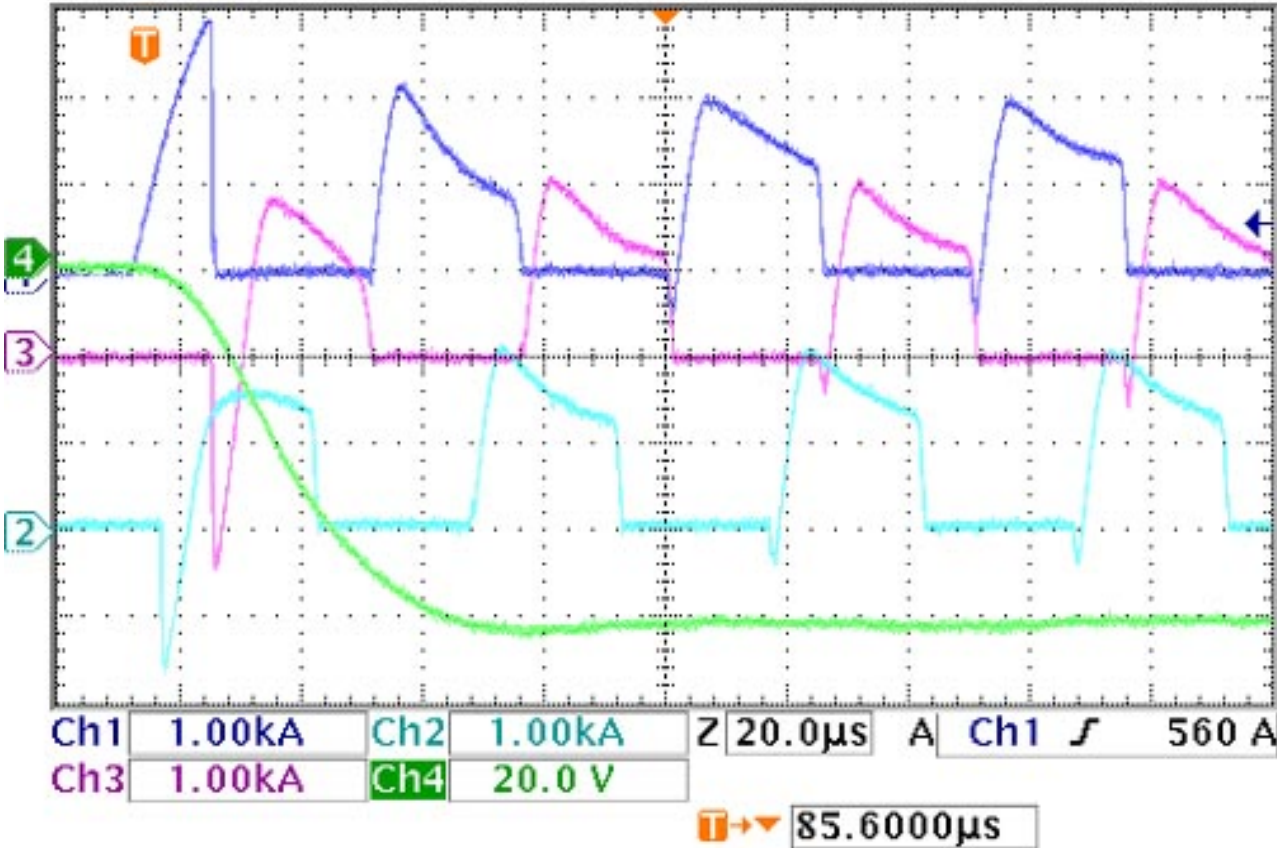
SCL-ME1 with 12 pack

Other units
not shown

12 Klystron, 75 kV Operation (9.25 MW)



Output Voltage
(~75 kV)



IGBT Switch Current
(1 kA/Div)

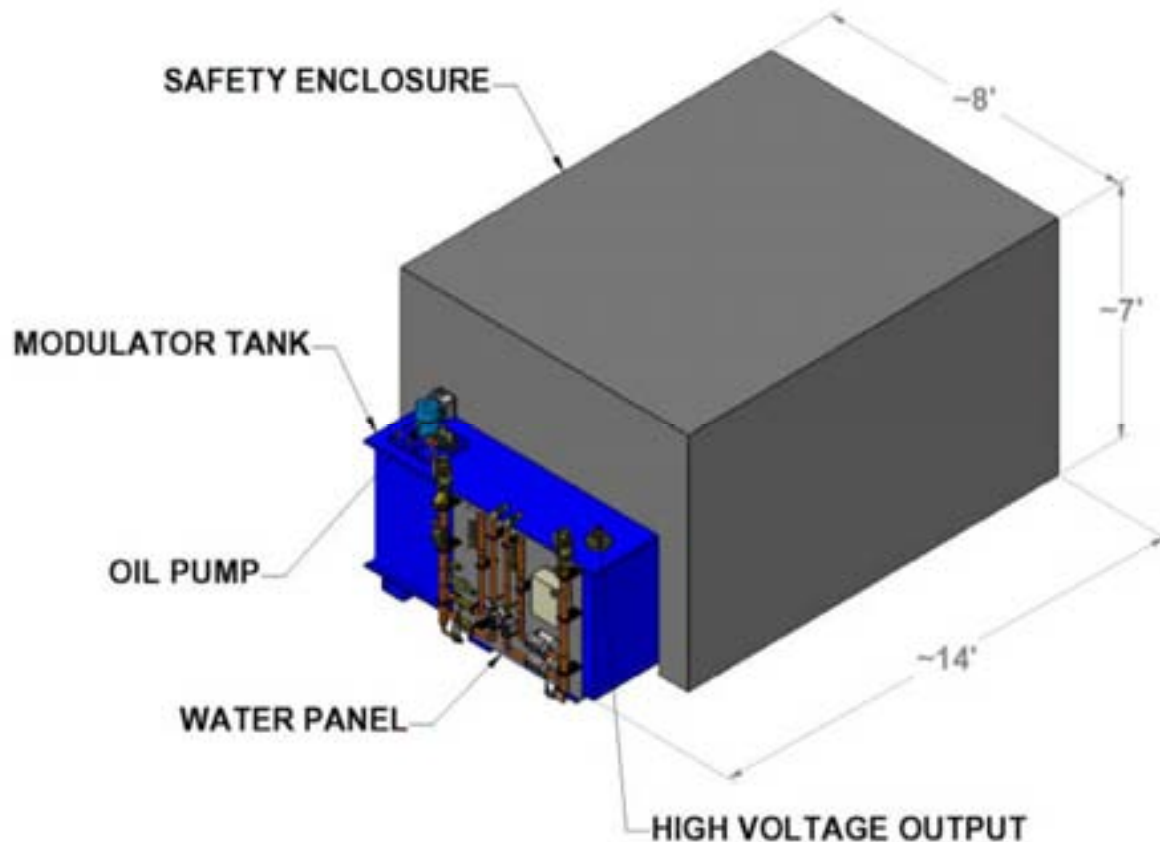
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Operational Efficiency

- 140 kV (5 MW Klystron), 800 kW Average Power
 - ~94% efficient
- 75 kV, “12 Pack” (550 kW klystrons)
 - ~93% efficient
- “Zero-Voltage-Switching” works
- Can be optimized to ~96% efficient for ILC Application
- Can Achieve ~90% Overall System Pulse Utilization Efficiency

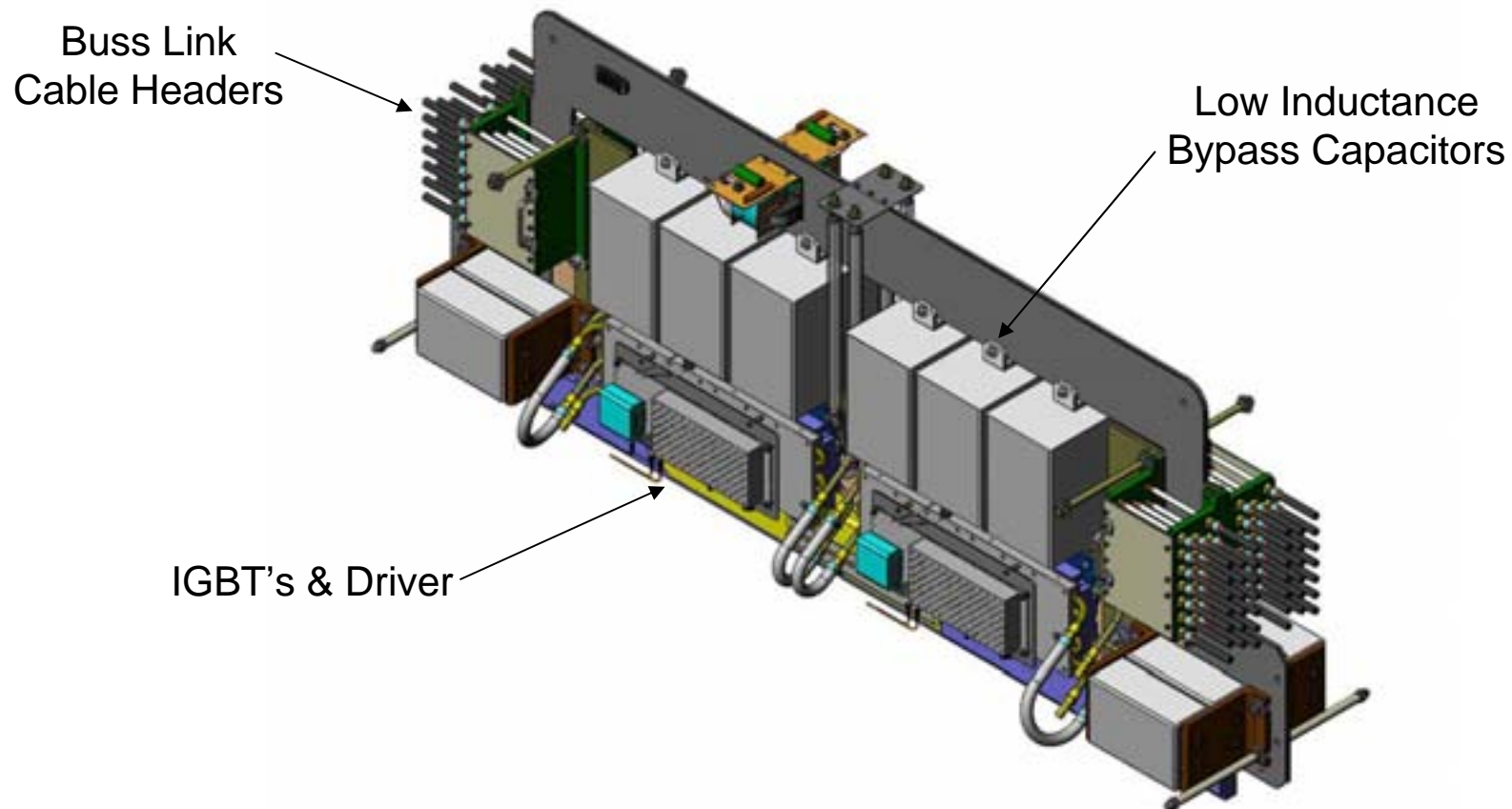
View Of Proposed 30 MW ILC Pentaphase Converter-Modulator System

Size: 7' X 8' X 14'

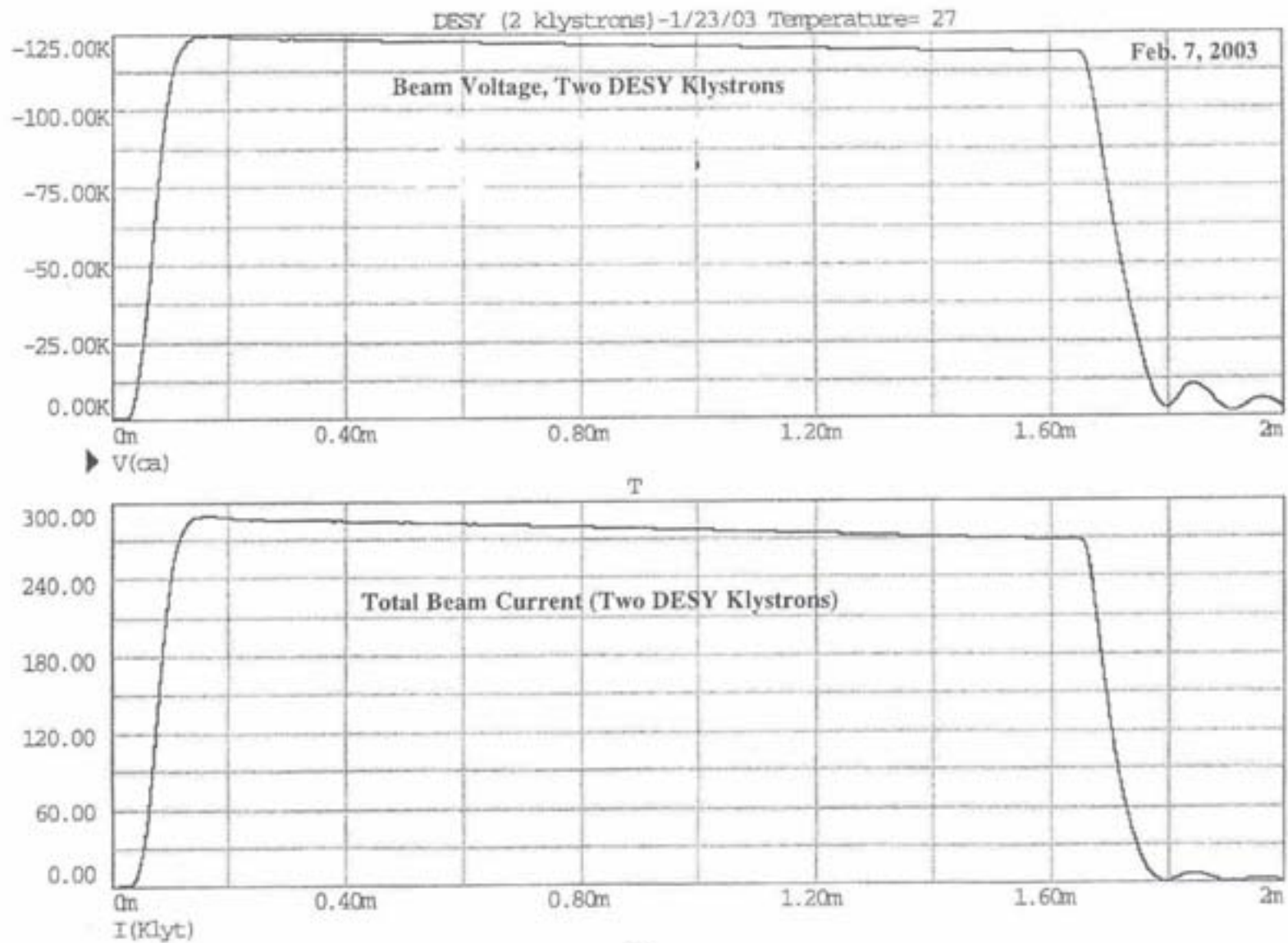


- Operates 2 MBK's
- Fault tolerant, automatic fault "ride-through"
- Can operate with long output cables (over 1 kilometer)
- Cannot harm klystron
- Multiple units operate from common DC bus
- Lower IGBT Loading than SNS Application
 - 900KW / IGBT (SNS)
 - 750KW / IGBT (ILC)

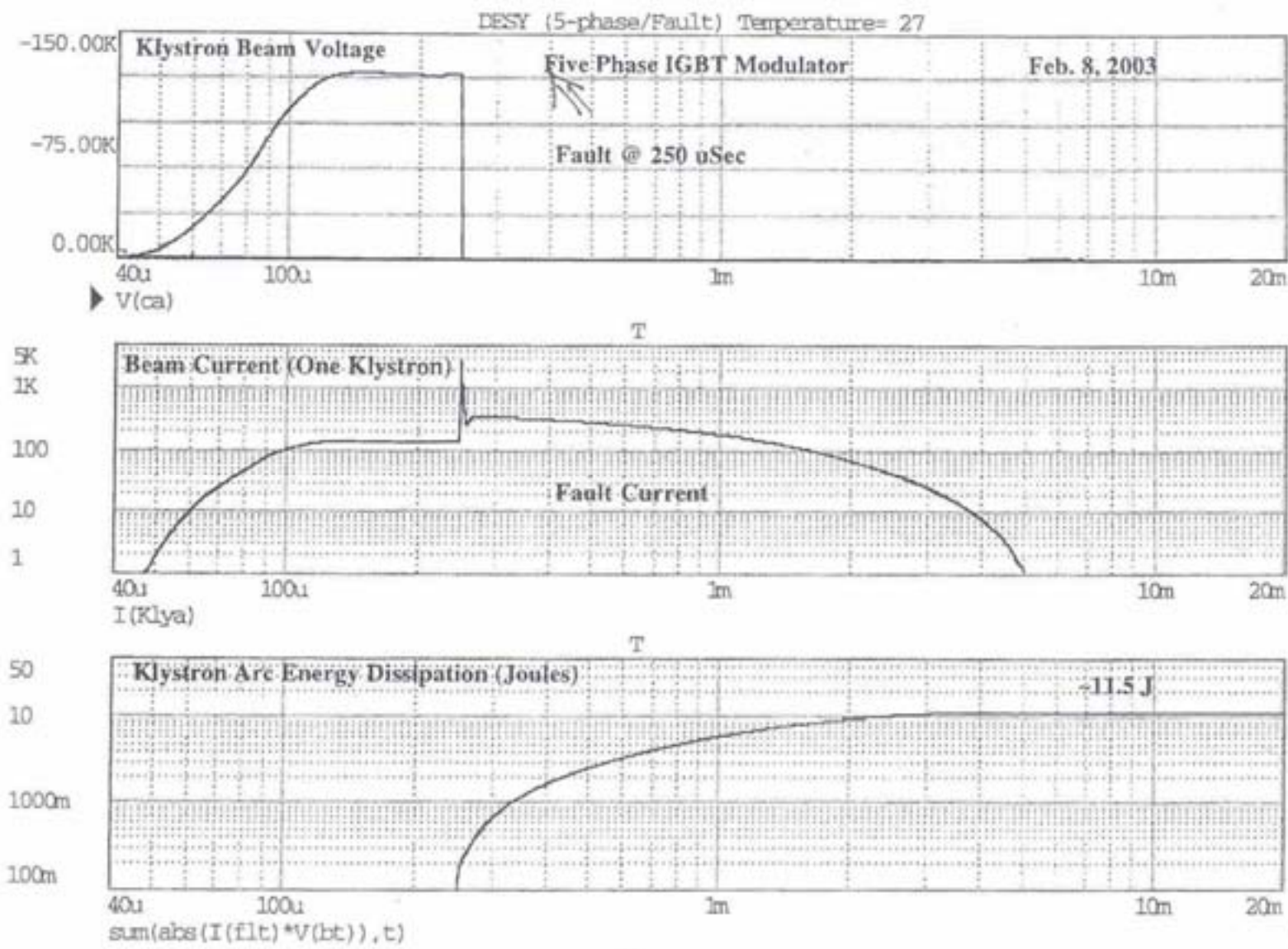
Dually IGBT Switch Plate



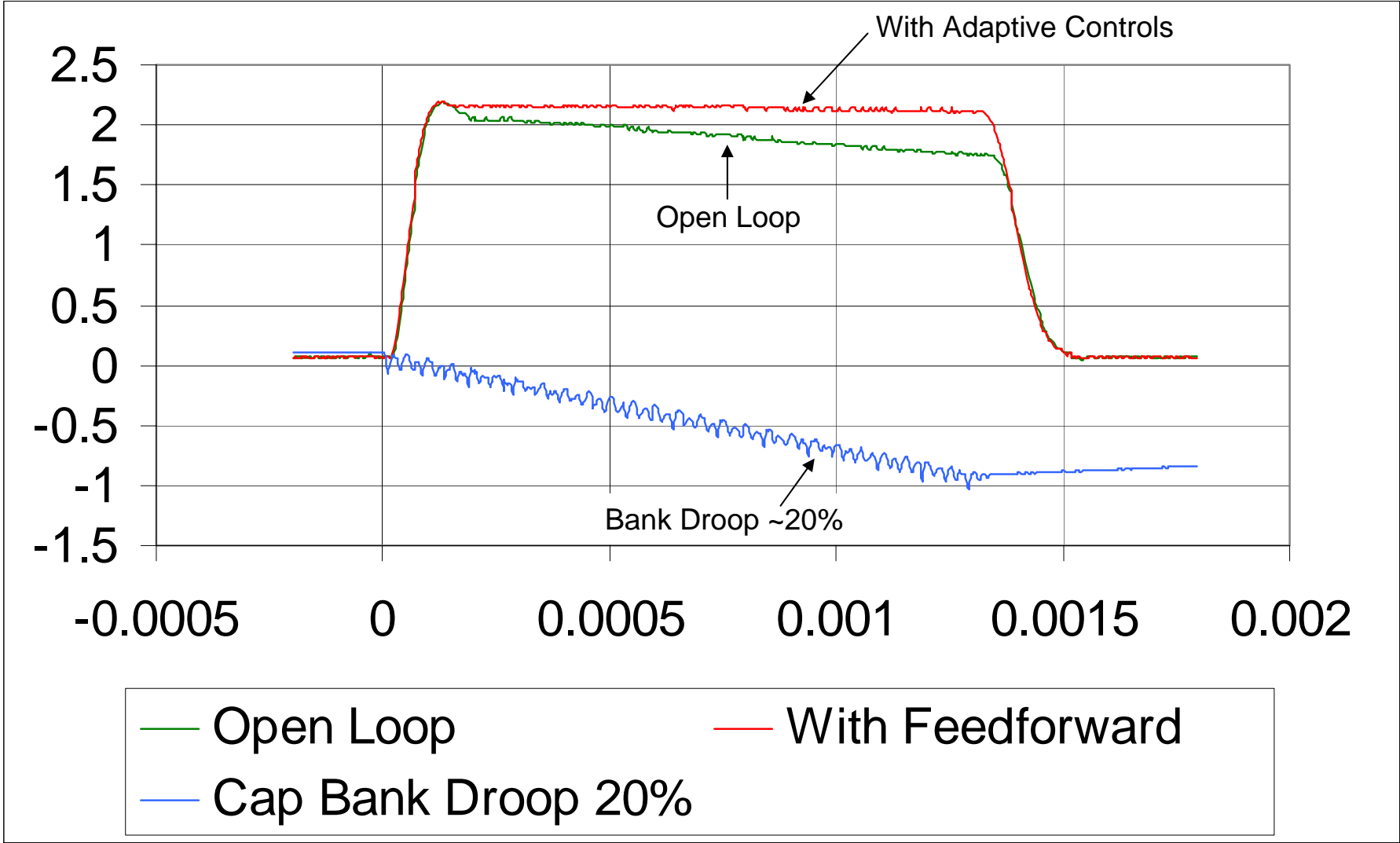
Beam Voltage And Current After 1KM Of Cable



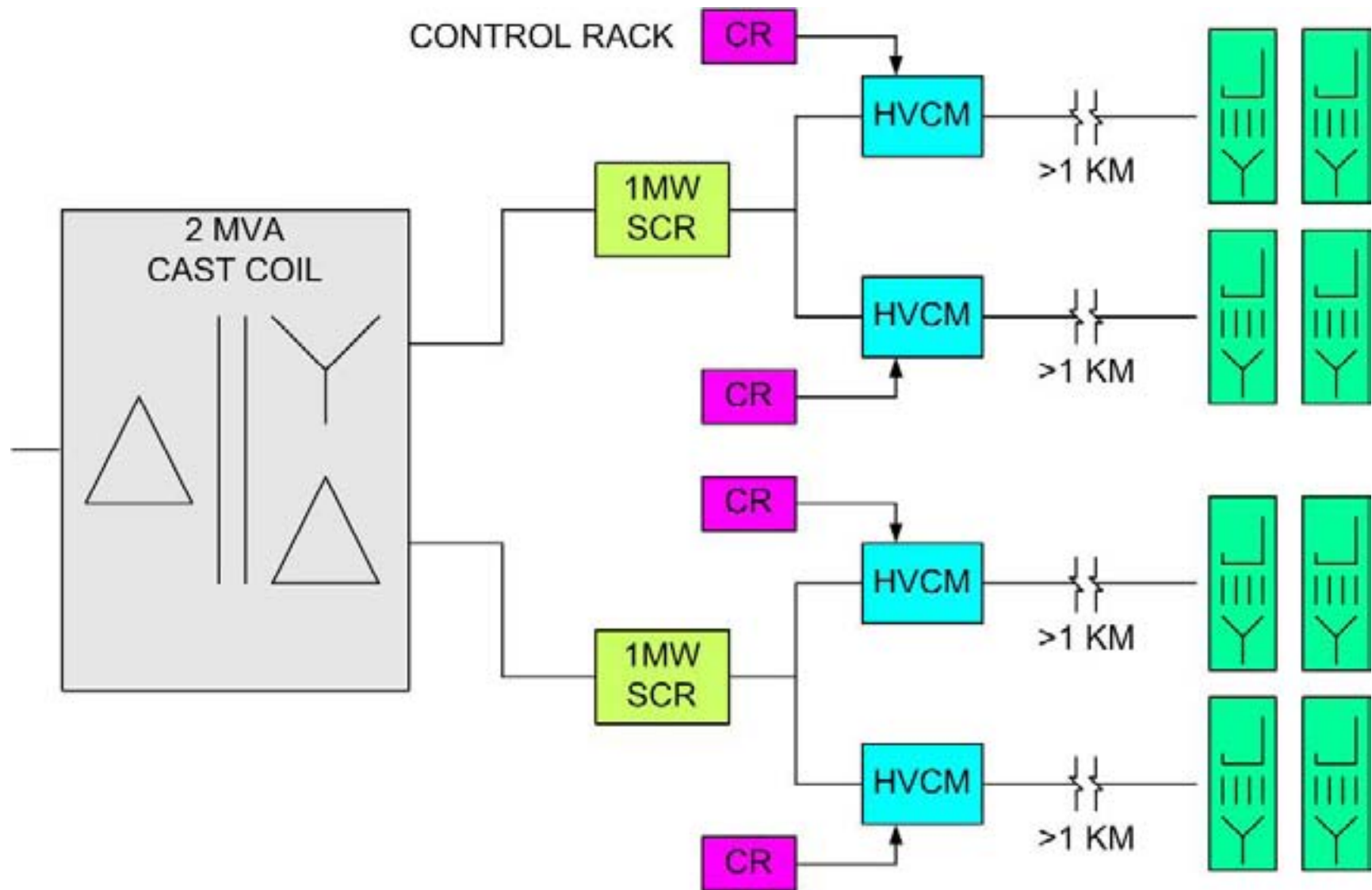
Klystron Fault Energy – 1KM Of Cable



Novel Adaptive Feedforward/Feedback For Modulator Control



Proposed ILC Configuration 1.5mS Pulses at 10Hz



Estimated Costs

2 MVA Substation (Cast Coil) 40K\$

1 MW SCR Controller (2 X 35K\$) 70K\$

“Dually Pentaphase” Converter (4 X 250K\$) 1M\$

Control Racks (4 X 40K\$) 160K\$

8-Tube Total 1.27M\$

~160K\$ / Tube

Suggested Development Path

- Operate SLAC Unit
- Upgrade SLAC System to one MBK Operation
 - “Dually” Switch Plate
 - Higher Current Diode Assemblies
- Test with >1KM Cable
- Improve Adaptive Control Method
- Complete Development of Pentaphase “Dually”
 - Operate 2 MBK’s
 - Operate with >1KM Cable
 - Evaluate Adaptive Controls

Conclusion

- Polyphase Resonant Power Conditioning design topology and techniques now proven
 - Easily Optimized
- Better understanding of component performance
- Inherently self and load protective
- Significant change in high power, power conditioning topology
- Testing, teaming, and prototypes desired for ILC applications
- Design is very cost effective and electrically efficient
- Installation space minimized
- Beam Tunnel space minimized